

# FY 2006 Topics TABLE OF CONTENTS

## **Defense Nuclear Nonproliferation**

Program Area Overview .....	3
1. Research to Support Proliferation Detection .....	3
2. Research to Support Nuclear Explosion Monitoring .....	7

## **Electricity Delivery and Energy Reliability**

Program Area Overview .....	9
3. Second Generation, High Temperature Superconducting Coated Conductors .....	10
4. Cryogenic Technology for Superconductors .....	11
5. Electric Transmission and Distribution Technologies .....	13

## **Environmental Management**

Program Area Overview .....	15
6. Decontamination and Decommissioning of Facilities in the DOE Complex .....	16

## **Biological and Environmental Research**

Program Area Overview .....	18
7. Measurement/Monitoring and Characterization Technologies for the Subsurface Environment .....	18
8. Genomes to Life and Related Biotechnologies .....	22
9. Atmospheric Measurement Technology .....	24
10. Medical Sciences .....	29
11. Carbon Cycle Measurements of the Atmosphere and the Biosphere .....	31
12. Biological Solutions for Reducing Atmospheric Carbon Dioxide and for Producing Fuels .....	34

## **Fossil Energy**

Program Area Overview .....	37
13. Capture and Sequestration of Carbon .....	38
14. Environmental Technology Innovations and Controls for Fossil Energy Facilities .....	41
15. Solid Oxide Fuel Cell (SOFC) Balance-of-Plant (BOP) .....	45
16. Coal Gasification and Combustion Technologies .....	49
17. Oil and Natural Gas Technologies .....	54

## **Basic Energy Sciences**

Program Area Overview .....	57
18. Advanced Fossil Fuels Research .....	57
19. Technologies Related to Energy Storage for Electric and Hybrid Vehicles .....	60
20. Manufacturing for the Hydrogen Economy .....	63
21. Separations Technologies .....	65
22. Nanotechnology .....	68
23. Chemical Solutions .....	71
24. Solid-State Light Emitting Diodes for General Illumination .....	74
25. Neutron, Electron, and Photon Beam Instrumentation .....	77
26. Materials for Advanced Nuclear Energy Systems .....	80

## **Nuclear Energy**

Program Area Overview .....	82
27. Advanced Technologies for Nuclear Energy .....	83

## FY 2006 Topics

### Energy Efficiency and Renewable Energy

Program Area Overview .....	84
28. Advanced Materials for New Energy Carriers, Services, and Products .....	85
29. Advanced Materials for Lightweight Vehicles .....	88
30. Advanced Materials for Process Technologies .....	90
31. Renewable Energy Sources .....	92
32. Advanced Motors, Power Electronics, and Sensors and Controls .....	95
33. Energy Efficient Membranes .....	99

### Fusion Energy Sciences

Program Area Overview .....	103
34. Advanced Technologies and Materials for Fusion Energy Systems .....	103
35. Fusion Science and Technology .....	108
36. High Energy Density Physics for Inertial Fusion Energy .....	112

### High Energy Physics

Program Area Overview .....	114
37. Accelerator Technology for International Linear Collider .....	115
38. Advanced Concepts and Technology for High Energy Accelerators .....	118
39. Radio Frequency Accelerator Technology for High Energy Accelerators and Colliders .....	121
40. High-Field Superconductor and Superconducting Magnet Technologies for High Energy Particle Colliders .....	124
41. High Energy Physics Detectors .....	126
42. High Energy Physics Data Acquisition and Processing .....	128

### Advanced Scientific Computing Research

Program Area Overview .....	132
43. High-Performance Computing .....	132
44. High-Performance Networks .....	135
45. High-Performance Middleware and Distributed Systems Technologies .....	137

### Nuclear Physics

Program Area Overview .....	138
46. Nuclear Physics Software and Data Management .....	139
47. Nuclear Physics Electronics Design and Fabrication .....	142
48. Nuclear Physics Accelerator Technology .....	145
49. Nuclear Physics Particle and Radiation Detection Systems, Instrumentation and Techniques .....	149

**FY 2006 Topics**  
**PROGRAM AREA OVERVIEW**  
**OFFICE OF DEFENSE NUCLEAR NONPROLIFERATION**

The Office of Defense Nuclear Nonproliferation is the organization within the Department of Energy's National Nuclear Security Administration (NNSA) responsible for preventing the spread of materials, technology, and expertise relating to weapons of mass destruction; and for eliminating inventories of surplus fissile material. Specifically the organization: [Secures nuclear materials, nuclear weapons, and radiological materials at potentially vulnerable sites in Russia and elsewhere](#); [Reduces quantities of nuclear and radiological materials](#); [Bolsters border security overseas](#); [Strengthens international nonproliferation and export control regimes](#); [Downsizes the nuclear weapons infrastructure of the former Soviet Union \(FSU\)](#); [Mitigates risks at nuclear facilities worldwide](#) and [Conducts cutting-edge nonproliferation and national security research and development \(R&D\)](#).

The following topics focus on nonproliferation research and development opportunities. The Office of Nonproliferation Research and Development conducts applied research and development, testing, and evaluation to produce technologies that lead to prototype demonstrations and resultant detection systems, strengthening the U.S. response to current and projected threats to national security worldwide posed by the proliferation of weapons of mass destruction (WMD) and the diversion of special nuclear material. DOE's NNSA is the only U.S. government agency investing in long-term strategic and often high-risk technical solutions to detect the proliferation of WMD. The R&D program is the technical base that provides operational agencies, including the Department of Defense (DOD) and the intelligence community, with innovative systems and technologies to meet their nonproliferation, counter-proliferation, and counter-terrorism responsibilities.

The Office develops applicable technologies, demonstrates and validates fieldable prototypes and, in the treaty monitoring area, provides actual operational hardware and software. The Office's work is focused in two programmatic areas: proliferation detection and nuclear explosion monitoring.

For additional information regarding the Office of Nonproliferation Research and Development priorities, [click here](#).

## **1. RESEARCH TO SUPPORT PROLIFERATION DETECTION**

The Proliferation Detection Program (PDP) applies the unique skills and capabilities of the NNSA and the DOE national laboratories and facilities to close nonproliferation technology gaps, identified through close interaction with other U.S. government agencies and in support of U.S. government policy. PDP develops the tools, technologies, techniques, and expertise to address the most challenging problems related to the detection, localization, and analysis of the global proliferation of weapons of mass destruction, with special emphasis on nuclear weapons technology and the diversion of special nuclear materials. In addition, PDP funds research that supports counter-proliferation and counter-terrorism missions, where there is synergy with the nonproliferation mission.

PDP facilitates long-term scientific innovation through sustained commitment to mission focused technical areas that build "best-in-the-world" competence. PDP also plays a key role in filling the critical middle ground between fundamental research and near-term acquisition, by using the unique skills of the national laboratories and plants as applied research integrators. Through the extensive relationships that the laboratories maintain with universities, basic science from academia and federal research programs are brought together to develop real-world system solutions based on classified insights into national security problems. PDP hands off technical know-how, which has been developed and validated, to U.S. Government acquisition programs and the U.S. industrial base to support national security missions. Technical advances, new proven methodologies,

## FY 2006 Topics

and improvements to capabilities are transferred to operational programs through technical partnerships; partnerships with industrial suppliers are often coordinated with user programs to facilitate successful outcomes. **Grant applications are sought only in the following subtopics:**

**a. Simulation, Modeling, and Algorithms**—Simulation, Modeling, and Algorithms (SAM), an enabling nonproliferation technology thrust area, seeks to develop advanced computational capabilities (ACC) to support the detection of the production, transport, assembly, and use of uranium and plutonium for non-peaceful purposes. Grant applications are sought to develop advancements in ACC information science, information technology, concepts using conventional sensor data, and performance modeling for broad classes of sensor systems:

- (1) Advanced capabilities in information science include new concepts and techniques for extracting information from sensor data and other sources for detection, measurement, classification, and data-sensor-information fusion. Areas of particular interest include evolutionary and genetic algorithms, machine learning, machine vision, data mining, image reconstruction or enhancement, distributed sensor networks with collective computation, Bayesian model averaging, federated analysis and networks, expert systems, and knowledge engines.
- (2) Advanced capabilities in information technology include new developments in basic theory; the software/firmware environment; and hardware that facilitates the creation of high performance, deployable, and adaptive processing equipment.
- (3) Advancements in the processing of sensor data are needed to detect and measure the distinctive characteristics of a target (such as movement, temperature, effluent or electro-magnetic emission) that can be used as input to a nuclear proliferation situation assessment.
- (4) The optimization of sensor system design and operation requires the development of physics-based performance models of the entire sensing process. Areas of interest include modeling the generation of observable signals from proliferation signatures, clutter discrimination and rejection, signal propagation through and distortion by the environment, signal interaction with the sensor, sensor noise characteristics, and the processing of the resulting measurements at a level of sufficient realism to make reliable assessments of sensor performance.

Questions – Contact Robert Mayo ([robert.mayo@hq.doe.gov](mailto:robert.mayo@hq.doe.gov))

**b. Nuclear Fuel Cycle Remote Sensing (Electro-Optical Systems): Hardware, Software, and System Development**—The DOE/NNSA Office of Nonproliferation Research & Engineering (NA-22) sponsors the development of detectors, sensors, and other enabling technology to improve the remote sensing of nuclear proliferation signatures. This subtopic is focused on two critical components that will enable the field-testing, evaluation, and eventual deployment of electro-optical sensors and their complementary data exploitation systems:

- (1) Tunable Infrared Quantum Cascade Lasers for Active Electro-Optical Remote Sensing: Quantum cascade lasers (QCL) have become one of the most relevant enabling technologies for electro-optical (EO) remote sensing of infrared (IR) signatures of proliferation activities. Grant applications are sought to develop improved QCL technology with special emphasis on: increased laser power increases; increased dynamic tuning range (100 wavenumbers or better); narrower linewidth; non-cryogenic cooling for the mid-wave IR (MWIR - 3-5 microns) and long-wave IR (LWIR - 8-14 microns) spectral regions; and increased stability and robustness in a high-vibration environment.

## FY 2006 Topics

(2) Remote Sensing Exploitation Tools for Nuclear Fuel Cycle Signatures: Users of state-of-the-art hyperspectral imagers (HSI) for the remote sensing of proliferation signatures struggle with lack of data exploitation tools. Friendlier software tools that allow users to maximize the extraction of actionable information from HSI remote sensing systems are needed. The bulk of the HSI data analysis is done by principal component analysis (PCA) and matched filter analysis. These methods, although effective, do not extract all the information from HSI data. Grant applications are sought to develop alternate methods to PCA and matched filter approaches to process HSI data. Alternate approaches of interest include, but are not limited to, independent component analysis (ICA), wavelet analysis, and Electromagnetic Impedance Spectroscopy.

Questions – Contact Juan Cuadrado ([juan.cuadrado@hq.doe.gov](mailto:juan.cuadrado@hq.doe.gov))

**c. Advanced Materials Research for Radiation Detection Applications**—The DOE/NNSA Office of Nonproliferation Research & Engineering sponsors the development of detectors, sensors and other enabling technology to enhance radiation sensing and detection for nonproliferation applications. Research that advances the state of the art in basic understanding of the form, function and capabilities of new detector material is needed. Grant applications are sought to develop:

(1) New materials – either scintillating or semiconductor – for detecting thermal neutrons, with 100% rejection of gamma-rays. In particular, a replacement for Helium-3 tubes and Li-6 doped fibers (which is inexpensive and simple to use) is needed.

(2) An unmoderated neutron detector, based on the development of a new material that allows for the recognition of a neutron recoil event and the complete discrimination of the neutron from a gamma-ray – the material should be suitable for use in coincidence counters, spectrometers, and imagers to determine the direction of fast neutrons.

(3) Materials, both scintillator and semiconductor, that can replace NaI and/or plastic scintillators and can be used in portal monitors. The new materials should be inexpensive, rugged, easy to fabricate into detectors, and provide resolution less than 3%.

(4) New semi-conductor materials that can be used to replace HPGe for high resolution (less than 1%) gamma-ray spectroscopy and can operate at ambient temperature.

Questions – Contact David Spears ([david.spears@hq.doe.gov](mailto:david.spears@hq.doe.gov))

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<http://www.osti.gov/energycitations/basicsearch.jsp>. Search for document title to find cited document as well as related reports, if any.

## 2. RESEARCH TO SUPPORT NUCLEAR EXPLOSION MONITORING

The Nuclear Explosion Monitoring Research & Engineering (NEM R&E) program is sponsored by the U.S. Department of Energy's (DOE) National Nuclear Security Administration's (NNSA) Office of Nonproliferation Research and Engineering. This program is responsible for the research and development necessary to provide the U.S. Government with capabilities for monitoring nuclear explosions. The NEM R&E program provides research products to the Air Force Technical Applications Center (AFTAC), which collects and analyzes data from a network of ground-based seismic, radionuclide, hydroacoustic, and infrasound data collection stations and satellite systems. Within the context of one or more of these technologies, research is sought to develop algorithms, hardware, and software for improved event detection, location, and identification at thresholds and confidence levels that meet U.S. requirements in a cost-effective manner. Grant applications responding to this topic must demonstrate how the proposed approaches would complement, and be coordinated with, ongoing or completed work (see list of ongoing contracts at <http://www.nemre.nnsa.doe.gov/coordination>) while improving capability. In addition, grant applications should address the manufacturability of any instruments or components developed. **Grant applications must be specifically related to nuclear explosion monitoring and must respond only to the following subtopics:**

**a. Seismic Monitoring of Nuclear Explosions**—Grant applications are sought to develop a low-distortion, analog-calibration signal source for testing 24-bit high-resolution digitizers. The source must provide: (1) up to 20 volts peak-to-peak into a 50 ohm load, with linearity better than -130 dB distortion, over the frequency range of 0.005 Hz to 200 Hz, selectable in 0.005 Hz steps; (2) an output current of 100ma peak; and (3) a capability of delivering 0.0025% frequency accuracy over its entire frequency range. Emphasis should be placed on creating a sine wave with less than 0.001% total harmonic distortion. Preferences will be given to signal generator designs that provide the capability for creating square wave signals (capable of synchronization with GPS within  $\pm 1.0$  microsecond) and band-limited white or shaped noise. The generator should be capable of two-tone signal production for inter-modulation distortion testing. Each of the two signals must have independent frequency and amplitude settings, allowing for standard two-tone formats. GPIB, RS-232, or USB interfaces should be provided to control all instrument functions.

Grant applications are also sought to develop a single-axis sinusoidal shake table to test highly sensitive seismometers. During its operation, the shake table must: (1) provide continuously variable peak accelerations, with a maximum acceleration of 1 g at 1 Hz; (2) produce a dynamic range of 120 dB from 0.01 Hz to 50 Hz; (3) support test payloads of up to 50 pounds; (4) introduce less than 1.0 ng of additive noise over the local seismic



## FY 2006 Topics

background noise; (5) be no less than 3 feet by 3 feet in size; (6) mount to an existing industrial concrete slab; and (7) be powered from a 110 V, AC source.

Questions – Contact Leslie Casey ([leslie.casey@hq.doe.gov](mailto:leslie.casey@hq.doe.gov))

**b. Radionuclide Monitoring of Nuclear Explosions**—Grant applications are sought to develop particulate samplers for atmospheric aerosols, which meet the following requirements: (1) total system weight less than 400 lbs, with a total system power requirement less than 1.2 kW; (2) trapping efficiency above 0.8 at flow velocities over 100 cm/s for particles of 0.05  $\mu\text{m}$ ; (3) a filter system that provides a flow of at least 25,000  $\text{m}^3$  of air per 24-hour period; and (4) a detector system with a sensitivity greater than 20  $\mu\text{Bq}/\text{m}^3$  ( $\text{Ba}^{140}$ ) for a 24-hour sample count duration. Grant applications may address either totally new systems or improvements to key components of existing systems that would significantly improve performance and meet the specifications listed above.

Grant applications are also sought to develop a device for producing liquid nitrogen in a field setting at a rate no lower than 12 liters per day. The device is needed for the cryogenic cooling of semiconductor detectors used in the field, along with certain chemical processes. In the past, the cooling requirement involved carrying large volumes of liquid nitrogen, or alternatively using mechanical coolers for the detectors, but these approaches are either too complex or require the storage of large amounts of liquid nitrogen. The new device must be compact, portable, field-robust, and efficient. Operation on world power (defined as 110V-240V and 50-60 cycles per second, see: <http://kropla.com/electric2.htm> or <http://www.voltageconverters.com/voltageguide.htm>) would be highly desirable, as would a module weight less than 50 lbs.

Questions – Contact Leslie Casey ([leslie.casey@hq.doe.gov](mailto:leslie.casey@hq.doe.gov))

**c. Space-Based Monitoring of Nuclear Explosions**—Grant applications are sought to develop advances in the use of composite materials in satellite payloads leading to significant weight reductions. While composites are currently used for some hardware (for example, sunshades), the electromechanical housings are currently fabricated from aluminum. Fabricating the current aluminum housing designs with a typical composite material could reduce the housing weight by 40%. For GPS housings, an overall system weight reduction of about 10% would be possible. Areas of technical interest include the development of: (1) specific composite materials qualified for aerospace applications; (2) composite panels that combine structural composites (for strength and stiffness), thermally conductive composites (for heat load management), and thin foils (for radiation shielding) – while such composite panels are currently fabricated with existing materials, they must be characterized to qualify for satellite applications; (3) advanced manufacturing techniques to enable the fabrication of components with tighter tolerances than those typically used in the fabrication of similar composite configurations; (4) composite modeling and analysis techniques to further the ability to design and understand the safety margins in composite hardware – such techniques include macromechanic approaches that allow modeling composites with homogenized material properties, micromechanic approaches to perform high fidelity analysis of interactions at the fiber and matrix boundaries, and design rules that govern the appropriate use of each approach; and (5) advanced materials that combine desirable properties (thermal, electrical, and shielding) into continuous composite materials (e.g., on-going research in carbon nanotubes is demonstrating promising results).

Grant applications are also sought to develop technology for deploying thin film materials on-orbit to form sunshades, resulting in reduced weight for these assemblies. While current sunshades are fabricated from composites, they still have significant weight, because they are designed to survive launch environments. The ability to deploy and form a sunshade on-orbit, using thin films, could lead to a reduction in weight. Approaches should include a lightweight deployment mechanism or deployment technique, with appropriate adjustments once deployed, to form and control the required shape. Therefore, in addition to developing the



## FY 2006 Topics

lightweight deployment mechanism and/or approach, grant applications should address: (1) control techniques for forming and stabilizing the thin films into the required final configuration, and (2) the development of thin film coatings with appropriate optical surface properties. One possible configuration would be a set of thin baffle rings, interconnected by a thin film; the configuration would be fully collapsed and stowed at system launch, then expanded and formed into its final configuration on-orbit.

Questions – Contact Vaughn Standley ([vaughn.standley@hq.doe.gov](mailto:vaughn.standley@hq.doe.gov))

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## PROGRAM AREA OVERVIEW OFFICE OF ELECTRICITY DELIVERY AND ENERGY RELIABILITY

The mission of the Office of Electricity Delivery and Energy Reliability is to lead a national effort to modernize and expand America's electricity delivery system in order to ensure a more reliable and robust electricity supply. This will be accomplished by actions that eliminate bottlenecks, foster competitive electricity markets, and expand technology choices. A modernized grid will significantly improve the Nation's electric reliability, efficiency, and affordability, and contribute to economic and national security. The risk of multi-regional blackouts will be reduced through better visualization and controls of the electric grid, superconductivity for electric systems, advanced cable design, storage and power electronics, use of distributed energy resources and micro-grids, as well as other technologies supported by the Office. Effective application of all these technologies requires development of less expensive, second generation, high temperature superconducting

## FY 2006 Topics

coated conductors, cryogenic technology for superconductors, and electric transmission and distribution technologies.

For additional information regarding the Office of Electricity Delivery and Energy Reliability priorities, [click here](#).

### 3. SECOND GENERATION, HIGH TEMPERATURE SUPERCONDUCTING COATED CONDUCTORS

Substantial worldwide advances have been achieved in recent years with respect to the development and processing of second generation, high temperature superconducting coated conductors (also known as “2G wires”). Compared to first generation wires, these coated conductors have the potential of providing lower cost and higher performance, and also provide the possibility of operation at moderate magnetic fields in liquid nitrogen. For short samples, very high current carrying capacities (i.e., greater than 400 A/cm at 77K) have been reported. For coated conductors longer than 100 meters, current capacities over 100 A/cm have been demonstrated. Nonetheless, further innovation and development will be needed to achieve the DOE 2010 vision for the commercial availability of 2G wires with a cost/performance ratio as low as \$10/kA-m (dollars per kiloampere-meter), and to fabricate the coated conductors in practical forms. **Grant applications are sought only in the following subtopics:**

**a. Multi-Functional Buffer Materials and Deposition Techniques**—Grant applications are sought to develop simplified buffer architectures and deposition techniques to lower the cost/performance ratio of coated conductors. Presently, coated conductor architectures consist of a flexible metallic substrate and a superconductor layer separated by three to five buffer layers of different thicknesses. These buffers, which include a texture formation layer, a cation diffusion barrier, an oxygen barrier, and a lattice parameter modifier, are deposited by a wide range of physical vapor deposition techniques. Most of these buffers serve a single function, thereby increasing the production cost of the multilayer conductor. The use of multi-functional materials could reduce the number of buffer layers. Also required are high-rate, high-performance, cost-effective buffer deposition techniques, in order to reduce the cost of coated conductors.

Questions – Contact Harbans Chhabra ([harbans.chhabra@hq.doe.gov](mailto:harbans.chhabra@hq.doe.gov))

**b. Technology to Increase the Current Capacity of Coated Conductors**—Grant applications are sought to increase the current capacity of coated conductors. Although very high current capacities have been achieved in short samples of coated conductors, these currents are still substantially lower than the DOE goal of 1,000 A/cm. Present approaches to increase the current capacity involve increasing the superconductor thickness and increasing the flux pinning capability of the superconductor. By combining these approaches, it may be possible to produce further increases in the current capacity. Alternatively, entirely new approaches may be required. Proposed approaches must demonstrate minimum current capacities of 600 A/cm at 77K self field and 150 A/cm at 77K 1 Tesla field for all field orientations. In addition, the proposed approaches must be industrially scalable and cost-effective.

Questions – Contact Harbans Chhabra ([harbans.chhabra@hq.doe.gov](mailto:harbans.chhabra@hq.doe.gov))

**c. Stabilized, Low-Loss, Low-Aspect-Ratio Coated Conductors**—Grant applications are sought to develop stabilized, low-loss, low-aspect-ratio coated conductors, suitable for winding into fully transposed cables. For practical applications, coated conductors and wires need to be stabilized against quenching and exhibit low AC-loss characteristics. To achieve stabilization, current approaches are investigating the inclusion of high-electrical-conductivity metallic stabilizers and the use of conductive buffers. To reduce AC losses, techniques such as filamentization or striation of the superconducting layer, in combination with twisting, are under study.

## FY 2006 Topics

Finally, conductors that have a low aspect ratio are desirable, in order to facilitate cable winding without compromising the mechanical integrity or engineering current density of the conductors. Innovations are sought to design, fabricate, and demonstrate these features, leading to conductors that are suitable for fully transposed wire and cables.

Questions – Contact Harbans Chhabra ([harbans.chhabra@hq.doe.gov](mailto:harbans.chhabra@hq.doe.gov))

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## 4. CRYOGENIC TECHNOLOGY FOR SUPERCONDUCTORS

In order to realize the benefits of using ceramic superconductors in electrical equipment, the superconductors must be maintained at temperatures well below ambient. The potential applications for these superconductors will most likely be if the operating temperature can be maintained economically in the range 63-83K. To economically achieve and maintain these temperatures, grant applications are sought to develop: (1) thermal insulation systems (cryostats) to reduce heat transfer from the ambient surroundings to the superconductor, (2) refrigerators (cryo-coolers) to remove heat from the cold region and transfer it to the ambient surroundings, and (3) high voltage cryogenic dielectrics suitable for these temperatures. **Grant applications are sought only in the following subtopics:**

**a. Cryostats**—Grant applications are sought to develop cryostats that are flexible, suitable for high-temperature-superconducting (HTS) electrical cable that might be placed underground or underwater, and offer superior performance and lower price compared to today's commercially available cryostats. For comparison, current flexible cryostats are manufactured in 100 m lengths, have a price of approximately \$480/m, admit heat at the rate of 2-3 W/m, and suffer performance declines at bends in the cable. Future HTS cables must be much longer (kilometers), have a reduced price (\$200/m), a reduced rate of heat invasion (e.g., less than 1 W/m), and avoid performance degradation at bends. In addition, the cryostats must be robust and maintenance free for at least ten years; research is needed to address vacuum integrity and performance of getter materials in the

## FY 2006 Topics

vacuum space of these long, flexible cryostats. (Note: utilities typically receive cable on spools having overall diameter of 2-3 m.)

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**b. Cryo-Coolers**—Grant applications are sought to develop cryo-coolers that are capable of unattended, maintenance-free operation for at least 10 years, and that can function in an underground and/or underwater environment. Proposed approaches must offer the prospect of future price reductions to less than \$40/watt at 65K.

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**c. Cryogenic Dielectrics for High Voltage Electrical Equipment**—Grant applications are sought to develop: (1) dielectric insulation suitable for use in large transformers, cable terminations, motors and generators, fault current limiters or other high voltage electrical equipment – the equipment should be capable of handling up to 138 kV in normal, steady-state operating conditions (note that motors and generators typically have terminal voltages of not more than 30 kV); (2) procedures to non-destructively test cryogenic dielectrics for voids and other defects (e.g., bubble formation and agglomeration) that engender partial discharge within the dielectrics; and (3) technology to monitor, test, and evaluate cryogenic dielectrics for the effects of "aging," the gradual decline in performance over the service life, which is observed in all dielectrics. For cryogenic dielectrics, it is likely that the principal causes of aging are partial discharges (which may be triggered by overloads), faults, and other undesired but expected events in the life of equipment that serves the electrical grid. A capability to anticipate the rate and extent of aging will be important to commercial adoption.

Questions – Contact Harbans Chhabra ([harbans.chhabra@hq.doe.gov](mailto:harbans.chhabra@hq.doe.gov))

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## 5. ELECTRIC TRANSMISSION AND DISTRIBUTION TECHNOLOGIES

Sensor, information, and communication technologies are needed to monitor and manage disturbance events in transmission and distribution (T&D) systems. These technologies are also critical for achieving optimized T&D system operations and maximized system capacities. The broad use of information and communication technologies has transformed many aspects of our modern-day society into an information-rich age. The Department of Energy plans to apply these same information/communication technologies to modernize our nation's electric delivery system. The end-state of this grid modernization not only will be a smart, reliable, and secure grid that protects against all disturbance events, but will also provide value-added services for economic prosperity. Modernizing the nation's grid system to reach this end state, however, will require significant investments on many fronts. **Grant applications are sought only in the following subtopics:**

**a. Advanced Voltage Sensor for High-Voltage Transmission Systems**—Grant applications are sought to develop a low-cost, optical sensor system for voltage measurement applications for overhead, high-voltage (69kV and above) transmission lines. The key performance requirements for the optical sensing system include: (1) real-time voltage measurements that are time synchronized (such as via GPS) and exhibit high accuracy and resolution; (2) fast sampling (microsecond sampling) of the transmission voltage; (3) little time latency from the voltage sensing to the sensor output interface; and (4) integration with electronics necessary for A/D conversion, communications, time synchronization, and use of standard interfaces. Additionally, it is preferred, though not required, that the same sensor system provide both voltage and current measurements on high-voltage transmission lines.



## FY 2006 Topics

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**b. Embedded Monitoring for Fault Anticipation**—Grant applications are sought to develop real-time system monitoring and diagnostic techniques that are built into the distribution equipment. The idea is to provide condition-based maintenance, as opposed to the time-based maintenance that is in typical practice today. The embedded sensor/monitoring system must monitor equipment performance, perform signature analysis on monitored data to correlate with actual equipment/system events, and detect any abnormal behaviors and/or pre-fault signatures for incipient failures. Distribution system components in need of embedded monitoring include: transformers, switchgears, capacitor banks, surge arresters, overhead cables for tree contacts, and underground cables. Grant applications must specify the target application(s) for pre-fault detection, describe what/how/where the monitoring data will be acquired, and describe the advancement(s) in signature analysis methodology that will be achieved to provide high correlation with actual system/equipment fault events associated with the target application(s).

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**c. Distribution System State Estimation**—The development of enhanced tools for the modeling and analysis of electric distribution systems is needed for the real-time estimation of the state of the distribution system. Grant applications are sought to develop: (1) load modeling and prediction tools for the improved resolution (temporal and end-use) of customer loads; (2) accurate sensitivity assessments of the impact of weather conditions, new technologies (i.e., distributed energy resources), demand response programs, and load curtailment practices; and (3) advanced algorithms and decision logics for the analysis of large data sets (i.e., expanded data parameters and volumes), including customer load data and the load-impacting factors listed in item (2) above. The improved modeling and analysis tools must maximize use of current system capacity and meet contingency planning and response requirements.

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**d. Standard Data Exchanges for Distribution System Management**—A standard data format and structure is needed to allow communication between the various software tools that are employed for distribution system analysis and management. Although several open and proprietary data formats are available at both transmission and distribution levels, they are not fully compatible or interoperable with the software tools at the distribution level. Therefore, grant applications are sought to develop common data tools for the conversion or translation of all open and proprietary data formats, in order to allow for data exchange and use by all distribution planners and operators. The data-exchange tools must support the interoperability of all data formats used as input for distribution system analysis and management tools, and must allow for the sharing of consistent, validated data on a regional or national scale. These data formats include the Supervisory Control and Data Acquisition (SCADA) system, along with legacy databases and external data sources (weather stations, call centers, outage management systems, geographic information systems, etc.).

Questions – Contact Eric Lightner ([eric.lightner@hq.doe.gov](mailto:eric.lightner@hq.doe.gov))

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### **PROGRAM AREA OVERVIEW ENVIRONMENTAL MANAGEMENT**

With the end of the Cold War, the Department of Energy (DOE) is focusing on understanding and eliminating the enormous environmental problems created by the Department's historical mission of nuclear weapons production. The DOE's Office of Environmental Management (EM) seeks to eliminate these threats to human health and the environment, as well as to prevent pollution from on-going activities. The goals for waste management and environmental remediation include meeting regulatory compliance agreements, reducing the cost and risk associated with waste treatment and disposal, and expeditiously deploying technologies to accomplish these activities. While radioactive contaminants are the prime concern, hazardous metals and organics, as defined by the Resource Conservation and Recovery Act (RCRA), are also important.

The responsibilities of DOE's Office of EM include the deactivation and decommissioning (D&D) of thousands of contaminated facilities. In addition to radioactive materials, many of the facilities are contaminated with hazardous materials, such as mercury, asbestos, and lead. DOE needs to reduce the volume of contaminated materials; therefore, new or improved technologies are needed to separate contaminants from surfaces such as concrete. These facilities also require continued monitoring and maintenance because deterioration could make them unsafe for workers to enter or increase the risk of contaminant release to the environment. DOE also needs to reduce risks to workers from potential exposures associated with D&D activities. Therefore, new or

## FY 2006 Topics

improved technologies are needed for monitors and/or sensors, especially for detecting airborne particulates containing metals, organics, or radionuclides.

The following topic solicits grant applications to develop technologies for D&D operations of facilities. The subtopics provide more detailed descriptions of specific needs.

For additional information regarding the Office of Environmental Management priorities, [click here](#).

## 6. DECONTAMINATION AND DECOMMISSIONING OF FACILITIES IN THE DOE COMPLEX

The DOE is responsible for the deactivation and decommissioning (D&D) of numerous buildings and facilities that have handled toxic and radioactive materials since the 1940s. These facilities were used for chemical separations, component and weapons fabrication, fuel/target fabrication, reactor operations, enrichment operations, and mining, milling, and refining. Deactivation refers to ceasing facility operations and placing the facility in a safe and stable condition to prevent unacceptable exposure of people or the environment to radioactive and other hazardous materials until the facility can be decommissioned. Decommissioning is the process of decontaminating or removing contaminated material and equipment to achieve the end state for the facility. Desired end states include complete removal and remediation of the facility, facility entombment, and release of the facility for either unrestricted or restricted use.

This topic focuses on issues of concern to D&D operations: removing contaminants from concrete, controlling airborne radiological contamination, and monitoring for hazardous contaminants or hazardous conditions within buildings. Among contaminated materials, concrete is pervasive within these buildings and facilities, and particular attention must be paid to recycling the concrete and disposing of concrete debris. Better control of airborne contaminants would further reduce health and safety risks to D&D workers and the environment during dismantlement or disassembly operations. New or improved monitors or sensors are needed to record exposure levels to workers or to monitor facility conditions to prevent potential environmental releases. **Grant applications are sought only in the following subtopics:**

**a. Separation Technologies for the Removal of Contaminants from Concrete**—The concrete in buildings and structures of DOE facilities is found in floors, walls, beams, posts, etc. The concrete might be found cast in place or in concrete blocks, and its surfaces may contain paint or other coatings. Since concrete is a porous material, contamination could have penetrated a short distance below the surface; if the concrete were cracked, the penetration might be much greater. Grant applications are sought for new or improved methods for removing solvents, toxic metals, and/or radionuclides from concrete, including contaminants that may have penetrated beyond the surface. One or more of the following forms of contaminated concrete should be addressed: (1) concrete in floors, walls, and other structures in existing buildings; (2) scabble particles (residue left after physical methods remove the outer inch or so of the concrete surface, where most contamination is concentrated); (3) concrete rubble remaining after building demolition. Grant applications must indicate what outcome (or range of outcomes) will be used to determine whether the proposed concept is working.

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**b. Control of Airborne Radiological Contamination**—Many facilities throughout the DOE complex are radiologically contaminated. This contamination has the potential to become airborne during dismantlement or disassembly operations as part of deactivation and decommissioning (D&D) activities. Radiological contamination poses safety and health risks to D&D workers, peripheral workers, and to the environment. Grant applications are sought to develop: (1) techniques to permanently affix the contamination without risking worker health or environmental release; (2) techniques to completely capture removable contaminants so that

## FY 2006 Topics

there is no possibility of airborne radionuclide particles; (3) low-cost systems or materials to control loose surface contamination in the form of low-level alpha emitters, which are difficult to detect but pose risks to worker health and safety; (4) a fixative to contain dispersible alpha contamination – the fixative must be easily applied to a variety of surfaces, last at least 20 years, and be easy to remove during the eventual decontamination of the facility; and (5) a method to capture airborne alpha contamination from a work area, such as a materials processing facility. Proposed approaches must not pose any additional hazard to workers. Any fixatives developed must meet Waste Acceptance Criteria (WAC) for the Waste Isolation Pilot Plant (WIPP).

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**c. Monitoring Within DOE Facilities for Hazardous Contaminants, Especially to Protect Workers, and for Determining Potential Hazardous Conditions**—Many facilities throughout the DOE Complex will reside in a safe storage or surveillance and maintenance (S&M) mode until such time that funding resources are available to perform decontamination and demolition. Typically, contaminant levels within facilities have been, or will be reduced to levels that minimize the likelihood of a release to the environment. However, long-term monitoring systems will still be required to ensure against, or provide rapid response to, facility conditions that could trigger a contaminant release. In addition, new or improved monitors or sensors are needed to record contaminant levels that would expose workers during deactivation and decontamination activities – to ensure that workers are not exposed to levels of hazardous contaminants that exceed exposure limits or other exposure criteria for the work environment. Grant applications are sought to develop: (1) remote techniques for the long-term monitoring for hazardous contaminants (e.g., radioisotopes, metals, volatile organics, etc.); (2) monitors or sensors to detect airborne contaminants to determine facility conditions or to determine exposure levels to workers (e.g., for plutonium isotopes, beryllium, mercury, lead, tritides, volatile organics, etc.); (3) monitors (especially, remote techniques) of facility conditions that could impact contaminant release (e.g., structural integrity, water infiltration, air movement, etc.).

Questions – Contact Justine Alchowiak ([justine.alchowiak@em.doe.gov](mailto:justine.alchowiak@em.doe.gov))

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**FY 2006 Topics**  
**PROGRAM AREA OVERVIEW**  
**BIOLOGICAL AND ENVIRONMENTAL RESEARCH**

The Biological and Environmental Research (BER) Program supports fundamental, peer-reviewed research in climate change, environmental remediation, genomics, systems biology, radiation biology, and medical sciences. BER funds research at public and private research institutions and at DOE laboratories. BER also supports leading edge research facilities used by public and private sector scientists across a range of disciplines: structural biology, DNA sequencing, functional genomics, climate science, the global carbon cycle, and environmental molecular science.

BER has a particular interest in the following areas:

- (1) Climate Change research aimed at the development of advanced climate models to describe and predict the roles of oceans, the atmosphere, ice and land masses on climate over time and research to understand how carbon dioxide moves through the environment, ways to increase its removal from the atmosphere, and its impacts on the Earth's climate and ecosystems.
- (2) Environmental Remediation research aimed at the development of advanced treatment options for nuclear waste, thereby extending the frontiers of methods for remediation, discovering the fundamental mechanisms of contaminant fate and transport in the environment and developing cutting edge molecular tools for investigating environmental processes will yield science-based strategies to reduce the costs, risks, and time for cleanup of DOE sites contaminated from years of weapons research.
- (3) Medical Sciences research aimed at the development of advanced imaging and other medical technologies including highly sensitive radiotracer detectors, radiopharmaceuticals, and new technologies such as an artificial retina that will give vision to the blind.
- (4) Life Sciences research aimed at the development of innovative solutions along unconventional paths to solve challenges in energy and the environment. Research is focused on developing a predictive understanding of microbes and microbial communities that will lead to the development of biotechnology solutions for producing biofuels such as cellulosic ethanol or hydrogen, help control greenhouse gases such as carbon dioxide and help clean up environmental contamination. This program also supports genomic DNA sequencing and research to understand the biological effects of low doses of radiation.

For additional information regarding the Office of Biological and Environmental Research priorities, [click here](#).

## **7. MEASUREMENT/MONITORING AND CHARACTERIZATION TECHNOLOGIES FOR THE SUBSURFACE ENVIRONMENT**

New measurement and monitoring tools for interrogating biological, chemical, and physical processes in subsurface environments are important elements of Department of Energy (DOE) research efforts supporting remediation performance assessment and DOE site stewardship. Objectives include determining the fate and transport of contaminants generated from past weapons production activities, assessing and controlling processes to remediate contaminants, and long-term monitoring of sites. Grant applications submitted to this topic must detail why and how proposed in situ fieldable technologies will substantially improve the state-of-the-art and must include bench and/or field tests to demonstrate the technology. Projected dates for likely operational deployment must be clearly stated. New or advanced technologies that can be demonstrated to operate under field conditions with mixed/multiple contaminants and that can be deployed in 2-3 years will receive selection priority. Claims of commercial potential for proposed technologies must be supported by

## FY 2006 Topics

endorsements from relevant industrial sectors, market analyses, or identification of commercial spin-offs. Grant applications that propose incremental improvements or enhancements to existing technologies are not of interest and will be declined, as will enhancements to predictive models.

For some of the following subtopics, collaboration with government laboratories or universities may speed the development and field evaluation of measurement or monitoring technology. Examples of potentially available DOE facilities are given below, including the Environmental Molecular Sciences Laboratory (EMSL), a DOE scientific user facility located at the Hanford Site in Richland, WA, that can provide analytical instrumentation and capabilities with direct application to sensor development and testing. Potential applicants are invited to review the Website for the EMSL Interfacial Chemistry and Engineering group

([http://www.emsl.pnl.gov/docs/ice/news\\_notes/homepage.html](http://www.emsl.pnl.gov/docs/ice/news_notes/homepage.html)) and the Interfacial and Nanoscale Science Facility (<http://www.emsl.pnl.gov/capabs/insf.shtml>) at the EMSL. Grant applications must describe, in the technical approach or work plan, the purpose and specific benefits of any proposed teaming arrangements.

**Grant applications are sought only in the following subtopics:**

**a. Mapping Hydrogeologic Processes in the Shallow Subsurface**—Accurate information about the distribution of parameters that control the flow of water in near-surface subsurface environments (vadose zone to water table), such as hydraulic conductivity, water content, and lithology are prerequisites to predict the flow and transport of contaminants. Natural heterogeneity and spatial variability of hydraulic conductivity are predominant factors that affect the subsurface flow. Geophysical data collected from the ground surface and between boreholes hold much promise for providing high-resolution information about the distribution of subsurface properties and associated uncertainties. In this subtopic, the emphasis is on describing water flow associated with contaminant transport processes.

Grant applications are sought to develop high-resolution geophysical sensors to: (1) detect hydrogeologic or geophysical processes that control the transport and dispersion of contaminants in the subsurface, or (2) measure mass-transfer processes and rates within and among individual flow paths in the subsurface. Small diameter applications (e.g., cone penetrometer technology (CPT) – a direct push technology for subsurface access) are of particular interest. Conventional logging tools for such applications typically provide information over relatively short distances (1-3 cm); therefore, a technology that can provide images, meters from the hole (such as the single well, cross well, and vertical seismic profiling methods developed for larger boreholes) are desired. The following issues should be addressed and tested: coupling, resonance, and power radiation.

While geophysical characterization methods are improving and yielding higher-resolution data, they have not routinely been used to describe flow and transport processes or for guiding remediation activities. Therefore, grant applications also are sought to measure these parameters and develop integrated, user-friendly software packages to facilitate the use of high resolution geophysical measurements for interpreting hydrogeologic properties. Proposed approaches must allow site personnel to utilize the information obtainable from non-invasive geophysical methods for improved subsurface characterization and monitoring.

Questions – Contact Michael Kuperberg ([michael.kuperberg@science.doe.gov](mailto:michael.kuperberg@science.doe.gov))

**b. Real-Time, In Situ Biogeochemistry Measurements in Subsurface Sediments, Biofilms, or Groundwater**—There is a need for sensitive, accurate, and real-time monitoring of changes in microbial community composition and metabolic potential as well as biogeochemical processes in contaminated subsurface environments, including sediments, biofilms, or ground water (hereafter referred to as the subsurface). Highly sensitive in situ monitoring devices for use in the subsurface are needed, particularly if they allow for low-cost field deployment in remote locations and an enhanced ability to monitor processes at finer levels of resolution. For this subtopic, the fate of the following radionuclides and metals are of interest: americium, cesium, chromium, cobalt, mercury, plutonium, strontium, technetium, and uranium. Grant



## **FY 2006 Topics**

applications that address other contaminants will be declined. Microbes and metabolic processes of interest are limited to those that may be involved in controlling the subsurface fate, transport and remediation of these elements. Grant applications should provide evidence of this relationship.

Grant applications are sought to develop innovative sensors and systems to detect biogeochemical processes that control the chemical speciation or transport of the aforementioned metals and radionuclides in the subsurface. Grant applications must provide convincing documentation (experimental data, calculations, etc.) to show that the sensing method is both highly sensitive (i.e., low detection limit), precise, and highly selective to the target microbe, microbial association, or analyte (i.e., free of anticipated physical/chemical/biological interferences). Approaches that leave significant doubt regarding sensor functionality in realistic multi-component samples will be excluded from consideration.

Grant applications are also sought for integrated sensing and controller/signal processing systems for autonomous or unattended applications of the above measurement needs. Innovative integration of components (such as micro-machined pumps, valves, and micro-sensors) into a complete sensor package with field applications in the subsurface will be considered responsive to this subtopic. Approaches of interest could include fiber optic, solid-state, chemical, or silicon micro-machined sensors; or biosensors (devices employing biological molecules or systems in the sensing elements) that can be used in the field. Biosensing systems may incorporate, but are not limited to, whole cell biosensors (i.e., chemiluminescent or bioluminescent systems), enzyme or immunology-linked detection systems (e.g., enzyme-linked immunosensors incorporating colorimetric or fluorescent portable detectors), lipid characterization systems, or DNA/RNA probe technology with amplification and hybridization. As substantial progress has been made in fiber optics and chemical sensing technology in the last decade, grant applications that propose minor adaptations of readily available materials/hardware, and/or can not demonstrate substantial improvements over the current state-of-the-art, are not of interest and will be declined.

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## **Availability of User Facilities and Other Specialized Resources**

The Environmental Remediation Sciences Division (ERSD) within the DOE Office of Biological and Environmental Research ([http://www.science.doe.gov/ober/ERSD\\_top.html](http://www.science.doe.gov/ober/ERSD_top.html)) has responsibility for programs and facilities that offer unique and complementary resources. Potential applicants are encouraged to consider use of these programs/facilities in development of applications.

- The Field Research Center (FRC) at Oak Ridge National Laboratory (<http://www.esd.ornl.gov/nabirfrc/index.html>) provides a DOE site location where scientists can conduct field scale research and obtain DOE relevant samples of soils, sediments, and ground waters for laboratory research. A useful general orientation for prospective investigators is available at [http://public.ornl.gov/nabirfrc/workshop2004\\_presentations.cfm](http://public.ornl.gov/nabirfrc/workshop2004_presentations.cfm).
- The Environmental Molecular Science Laboratory (EMSL) at the Pacific Northwest National Laboratory, (<http://www.emsl.pnl.gov>), is operated by ERSD as a national scientific user facility with state-of-the-art instrumentation in environmental spectroscopy, high field magnetic resonance, high performance mass spectroscopy, high resolution electron microscopy, x-ray diffraction, and high performance computing.
- ERSD ([http://www.sc.doe.gov/ober/ober\\_top.html](http://www.sc.doe.gov/ober/ober_top.html)) provides user support for experiments at synchrotron light sources that are capable of providing structural and chemical information often unavailable with conventional sources of x-rays. DOE laboratories with synchrotrons supporting ERSD research and



## FY 2006 Topics

points of contact include: Argonne National Laboratory (<http://www.aps.anl.gov/index.html>), contact Ken Kemner ([kemner@anl.gov](mailto:kemner@anl.gov)); Brookhaven National Laboratory (<http://www.nsls.bnl.gov/>), contact Jeffrey Fitts ([fitts@bnl.gov](mailto:fitts@bnl.gov)); Lawrence Berkeley National Laboratory ([http://esd.lbl.gov/als\\_environmental\\_program/](http://esd.lbl.gov/als_environmental_program/)), contact Susan Hubbard ([sshubbard@lbl.gov](mailto:sshubbard@lbl.gov)); and Stanford Synchrotron Radiation Laboratory (<http://www-ssrl.slac.stanford.edu/mes/remedi/index.html>), contact John Bargar, [bargar@slac.stanford.edu](mailto:bargar@slac.stanford.edu)). Use of the synchrotron light sources requires a separate approval process.

- A description of the nature and extent of contamination at the principal DOE sites is available at <http://www.nap.edu/books/0309065496/html/index.html>. More detailed information is available in some cases from the major DOE sites:

Hanford [<http://www.hanford.gov>, <http://www.hanford.gov/cp/gpp/>, <http://www.hanford.gov/cp/gpp/science/sandt.cfm>];  
Idaho National Laboratory (<http://www.inl.gov/geosciences/vadosezone.shtml>);  
Oak Ridge Reservation (<http://www.oro.doe.gov/em/>) and  
Savannah River Site (<http://www.srs.gov/general/srs-home.html>,  
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## 8. GENOMES TO LIFE AND RELATED BIOTECHNOLOGIES

The Department of Energy (DOE) supports research to acquire a fundamental understanding of biological and environmental processes. This includes the display of genomes as DNA sequences; the functional characterization of gene products, especially from DOE-relevant microbes; structural biology user stations at synchrotron sources and neutron sources; computational genomics; and the development of integrated information systems. This topic is focused on the goals of the Genomes to Life (GTL) program, namely, to develop a detailed understanding of the molecular machines of DOE-relevant microbes and their networking in living cells and microbial communities. Microbes with capabilities that can further several DOE programmatic missions are being used as the current subjects for these studies. The knowledge thus gained is enabling both the public and private sectors to apply genome knowledge to bio-production of energy, promote environmental applications such as bioremediation and carbon sequestration, promote cleaner industrial processes, and enable increasingly effective computational models of the microbial cell. For some of the subtopics below, capabilities already exist in a few laboratories, but commercial involvement will be needed before the technology can be exported to the broader research community. **Grant applications are sought only in the following subtopics:**

## FY 2006 Topics

**a. Genome Scale Reagent Sets**—The number of genomes is rapidly increasing. These genes, displayed as sequenced chromosomes with their constituent genes, number in the thousands for bacteria and in the 10-100 thousand range for higher organisms. Each gene may give rise to numerous distinct mRNAs and proteins, through processes of alternative RNA splicing and post-translational modifications. Although micro-arraying methodologies are enabling highly parallelized interrogations of huge macromolecule collections, production and management systems are required to assure the availability of the numerous analytical reagents that are needed in small quantities. Grant applications are sought to develop: (1) systems that will produce thousands of affinity reagents (oligo-nucleotides, synthetic genes, antibodies, and other affinity reagents) in pico-molar quantities with good quality control, and (2) miniaturized delivery systems for such reagent sets.

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**b. Proteomics**—A number of proteomics tasks are being pursued to achieve the goals of the GTL program. These tasks include high throughput production and purification of proteins, correlation of proteins with the genes encoding their primary structure, identification of protein isoforms encoded by the same gene, identification of memberships in functional complexes of proteins, and identification of the variations of proteome constituents under change to useful physiological states. However, a number of obstacles hinder the efficient accomplishment of these tasks. For example, several host-vector systems are available for the production of proteins encoded in a hyper-expressed source gene; yet, for some source genes, the proteins fail to fold into physiologically effective three-dimensional conformations (entrapment in insoluble inclusion bodies is one cause of such failures). Another difficulty is that proteins targeted to membranes are problematic. Lastly, the lack of affinity reagents that bind to proteins in their native conformations adversely impacts structure, protein association, and function analyses. Therefore, grant applications are sought for the improved recovery and analysis of effective proteins. Areas of interest include: (1) the production of solubilized proteins in active conformations, with or without post-translational modifications; (2) the development of synthetic membranes or nano-structures enabling analyses of membrane proteins; (3) and the development of improved affinity reagents.

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**c. Instrumentation and Products Needed for Single Macromolecule Analysis and Control**—Over the last decade, research laboratories have made substantial progress in developing instrumentation for the interrogation and manipulation of single macromolecules. Techniques include the use of optical-laser tweezers, atomic force microscopy, and single molecule fluorescence microscopy. Although the effectiveness of these techniques has improved steadily and the instrumentation is now robust, most of these single-molecule biophysics instruments are locally built. The lack of commercial support has severely hindered the export of these technologies to the broader user community. Grant applications are sought to expand the commercialization of techniques, instrumentation, products, and software systems that would enable the broader usage of single macromolecule analysis methods. To fulfill a complementary need, grant applications also are sought to develop specimen arraying systems effective at micro to nano-scales, and microfluidics-based management systems.

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**d. Informatics**—A continuing GTL need is more efficient processing of increasingly large data sets, which are generated by experimental groups. For example, there is a current need for automated identification of protein modifications from the mass spectra of trypsinized proteomic samples. Grant applications are sought to improve one or more of the component software packages that have already been developed by laboratory groups, in order to enhance user friendliness and thereby support their broad export to the biologist community. Of particular interest are approaches related to: (1) systems biology, (2) the processing of proteomics and metabolomics data sets, (3) improved integration and or querying of heterogeneous data sets, and (4) the automated development of cellular metabolic models from data sets on newly studied microbes. Grant

## FY 2006 Topics

applications are also sought to develop novel software in support of cellular modeling with predictive capabilities.

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## 9. ATMOSPHERIC MEASUREMENT TECHNOLOGY

World-wide energy production is modifying the chemical composition of the atmosphere and is linked with environmental degradation and human health problems. The radiative transfer properties of the atmosphere may be changing as well. Various technological developments are needed for high accuracy and/or long term monitoring of these changes to support a strategy of sustainable and pollution-free energy development for the future. Grant applications must propose Phase I bench tests of critical technologies with respect to the subtopics that follow. (“Critical technologies” refer to components, materials, equipment, or processes that overcome significant limitations to current capabilities.) For example, grant applications proposing only computer modeling without physical testing will be considered non-responsive. Grant applications should also describe the purpose and benefits of any proposed teaming arrangements with government laboratories or universities in the technical approach or work plan. Applications submitted to any of the subtopics should support claims of commercial potential for proposed technologies (e.g., endorsements from relevant industrial sectors, market

## FY 2006 Topics

analysis, or identification of potential spin-offs). **Grant applications are sought only in the following subtopics:**

**a. Measurements of the Chemical Composition of Carbonaceous Aerosols**—There is a need to develop improved measurement methods to characterize the bulk and the size-resolved chemical composition of ambient aerosols in real time, particularly carbonaceous aerosols. Improved measurements would facilitate the identification of the origin of aerosols, i.e. primary versus secondary and fossil fuel versus biogenic. Also, they would help to elucidate how aerosol particles are processed in the atmosphere by chemical reactions and by clouds, and how their hygroscopic properties change as they age. This information is important because relatively little is known about organic and absorbing particles, which are abundant in many locations in the atmosphere. In particular, there is a need for instruments suitable for real-time measurements of the composition of particles at the molecular level. Although recent advances have led to the development of new instruments such as particle mass spectrometers and single particle analyzers, these instruments still have important limitations in their ability to quantify black carbon vs. organic carbon, provide speciation of refractory and volatile organic compounds, and calibrate both organic and inorganic components. Therefore, grant applications are sought to improve these instruments, or develop new technology, in order to provide one or more of the following attributes related to the measurement of the chemical composition of carbonaceous aerosols: (1) quantifiable results over a wide range of compounds – a problem for laser ablation aerosol mass spectrometer methods; (2) measurements over a range of volatility so that dust, carbon, and salt are detectable – a problem for thermal decomposition aerosol mass spectrometers; (3) speciation of individual organics, including those containing oxygen, nitrogen, and sulfur; (4) identification of elemental carbon and other carbonaceous material, so that the makeup of the absorbing fraction is known; (5) measurements with high time resolution – an inherent problem with filter techniques; (6) identification of source markers, such as isotopic abundances in aerosols; and (7) the ability to probe the chemical composition of aerosol surfaces.

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**b. Instrumentation for Characterizing Atmospheric Aerosols**—Improved instrumentation and techniques are required to understand other characteristics of atmospheric aerosols. This subtopic deals with three of them:

**(1) Aerosol precursors.** Improvements in gas phase chemistry are needed to further understand the evolution of aerosols in clouds. For example, gas phase measurements of  $\text{H}_2\text{SO}_4$ , a major aerosol precursor, have revealed a wealth of new information in the last decade. To make further progress, grant applications are sought to develop instruments that can make fast measurements of  $\text{NH}_3$ , ion clusters, and gas phase organics, substances that might either condense or dissolve into preexisting aerosols or cloud droplets.

**(2) Aerosol absorption.** The aerosol absorption coefficient, together with the aerosol scattering coefficient, determines the single-scattering albedo. This key aerosol property, along with the factors that contribute to it, are critical for determining heating rates and climate forcing by aerosols. Therefore, grant applications are sought to develop reliable instruments for the *in situ* measurement of the single-scattering albedo for particles containing black and organic carbon, dust, and minerals. The measurements must cover the solar wavelengths (UV, visible, and near infrared), must not alter aerosol properties, and must address the influence of relative humidity.

**(3) Aerosol size distributions.** Knowledge of the particle size distribution is essential for describing both direct and indirect radiative forcing by aerosols. However, current techniques for determining these distributions are often ambiguous because of the assumption that the particles are spherical. In particular, the optical techniques most often used in the 0.5-10  $\mu\text{m}$  size range have inherent problems. Therefore, grant applications are sought for techniques to determine the size distribution of ambient aerosols, in the 0.5-10  $\mu\text{m}$  size range, that are not based on optical properties. The techniques must address the influence of relative



## FY 2006 Topics

humidity and must be integrated with the simultaneous measurements of such properties as mass, area (extinction), and number.

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**c. Instrumentation for Characterizing UV Spectrum and Radiative Forcing of Aerosols**—Improved measurements of backscatter lidar and aerosol optical properties are required to understand the sub-visual and radiative forcing aspects of aerosols. This subtopic deals with two of these measurement needs:

**(1) Eye-safe, UV backscatter lidar for detection of sub-visual cirrus.** Backscatter lidar detection in the UV presents an attractive solution for the reliable autonomous detection of sub-visual cirrus, particularly in the tropics where the existence of sub-visual cirrus is certain but its prevalence is unknown. For these clouds, molecular scattering increases with shorter wavelength, yielding a larger signal above the cloud top with a commensurately more robust determination of cloud optical depth. More significantly, eye-safety constraints are greatly relaxed, permitting up to one thousand times the output laser power. Improvements in solid-state laser technologies have yielded commercial lasers capable of producing these higher powers in the UV. Grant applications are sought to develop autonomous backscatter lidar in the UV (nominally 355 nm), with pulse energies of 100-200 mJ at pulse rates between 100-5000 Hz, which are capable of detecting the sub-visual cirrus at ranges from 60 meters to 20 km with at least 30-meter resolution. The lidar also must provide polarization-sensitive detection of the return signal, in order to determine the cloud phase. Phase I should demonstrate the feasibility of the technology in the laboratory, including at least a 50-fold increase in the signal-to-noise ratio compared to existing micropulse lidar, at altitudes greater than 10 km.

**(2) Instrumentation for Remote Sensing of Aerosol Phase Function.** The radiative forcing of aerosols depends on the vertical distribution of the aerosol scattering coefficient, the absorption coefficient, and the phase function [15]. For the usual situation of optically thin aerosols, the top-of-the-atmosphere radiative forcing depends only on the scattering coefficient and phase function (and solar zenith angle). The phase function of aerosols is highly variable, depending on the size distribution and (for dust and soot aerosols) on particle shape [16]. *In situ* techniques can measure the scattering coefficient [17] and potentially the phase function [18]. However, these techniques depend on the reconstruction of inhomogeneous vertical profiles from samples taken by aircraft at a small number of atmospheric levels. In addition, the aircraft observations are severely limited in frequency of operation. As a consequence the reconstructions are error prone. Other remote sensing techniques (e.g., Raman lidar [19]) can measure profiles of aerosol backscattering and extinction, but not the complete phase function needed to calculate the radiative forcing.

Grant applications are sought to develop new ground-based instrument technology for the remote sensing of aerosol scattering coefficient and phase function. Measurement of partial information about aerosol phase functions, such as asymmetry parameter, backscatter fraction, or the detailed function over a substantial portion of scattering angle, will be considered responsive. The instrumentation should be able to measure the required aerosol optical properties for typical rural continental aerosol loadings. Although measurements throughout the lower troposphere are preferred, it will still be acceptable if the measurements can be made in the boundary layer, at least. Also preferred is the measurement of optical properties at two widely separated wavelengths in the UV-visible spectrum; however, measurement at only one wavelength will be considered acceptable. Phase I should demonstrate the feasibility of the technology in a simple field test. In Phase II, an operational sensor should be built, tested, and compared with existing aircraft measurements *in situ* and with existing remote sensing instruments.

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## FY 2006 Topics

**d. UAV-Suitable Cloud Radar**—The collection of high-resolution airborne radar data, required for retrieving cloud properties, is crucially needed by the Atmospheric Radiation Measurement – Unpiloted Aerial Vehicle (ARM-UAV) Program. These data are needed to extend ground-based and satellite-based retrievals of cloud properties to other temporal and spatial scales, develop parameterizations of cloud processes for models, and evaluate the performance of general circulation models and cloud-resolving models. In addition, there is a strong need for state-of-the-art retrievals of the vertical structure of ice and liquid clouds using Doppler radar. UAVs have a number of operational characteristics that make them well suited for the long-endurance, high altitude measurements that are needed to address the largest source of uncertainty in future global warming scenarios: the interaction of clouds with solar and thermal energy. Although the ARM-UAV Program has integrated instruments on a variety of UAVs and piloted aircraft – and has conducted measurement campaigns in conjunction with ground-, aircraft-, and satellite-based observations to investigate cloud and solar/thermal radiation properties – the development of a suitable cloud radar for these platforms remains a current need.

Therefore, grant applications are sought to develop a cloud radar suitable for UAVs and piloted aircraft. The desired characteristics of the new cloud radar include: (1) the need for minimum operator intervention for time periods from 8 to 10 hours; (2) minimum weight (50 kg is the target for maximum weight), size, and power consumption; (3) operation at high altitudes (up to 65K ft); (4) sensitivity of at least -35 dBZ at 2 km and -40 dBZ at 1 km, with higher sensitivity desired; (5) maximum vertical resolution of 60 m, with 30 to 45 m desired; (6) horizontal resolution of 100 m at 200 m/sec (implies integration time of 0.5 s); (7) flexibility to change characteristics during flight (pulse width, integration time, range); (8) down-looking operation at 94 GHz; (9) the ability to measure reflectivity and Doppler velocity, with polarization desired; (10) a Nyquist velocity of 10 m/s, with 20 m/s desired; (11) no need for pulse compression in order to profile the whole troposphere; (12) an absence of radio frequency interference with other payload instrumentation; (13) the collection of spectra to allow for post-processing of Doppler moments after flight; (14) sufficient data storage capacity (minimum of 15 to 20 Gigabytes); (15) a reliable design, even if this reduces features; (16) a flexible interface between internal components and antenna, in order to allow for mounting on alternate aircraft platforms and for a possible scanning mechanism; and (17) an antenna size no larger than 30 cm, with 20 cm desirable.

Interested parties responding to this need will be expected to work with the ARM-UAV Program to refine the requirements and coordinate design features.

Questions – Contact Michael Huesemann ([michael.huesemann@pnl.gov](mailto:michael.huesemann@pnl.gov))

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## 10. MEDICAL SCIENCES

The Department of Energy (DOE) Medical Sciences program covers a broad range of energy-related technologies including nuclear medicine and advanced imaging instrumentation. DOE is interested in innovative research involving medical technologies to facilitate and advance the current state of diagnosis and treatment of human disorders.

Principles of physics, chemistry, and engineering are being employed to advance fundamental concepts dealing with human health, to utilize the study of molecular interactions for a better understanding of organ function, and to develop innovative biologics, materials, processes, implants, devices, and informatics systems for the prevention, diagnosis, and treatment of disease and for improving human health. The DOE Advanced Medical Instrumentation program seeks to capitalize on the unique physical sciences and engineering capabilities at the DOE's national laboratories to develop new technologies that will have a significant impact on human health.

With respect to nuclear medicine, current areas of research include the development of: (1) radiopharmaceuticals as radiotracers to study *in vivo* chemistry, metabolism, cell communication, and gene expression in normal and disease states, and as therapeutic agents; and (2) new radionuclide imaging systems.

**Grant applications are sought only in the following subtopics:**

**a. Development of Non-Photovoltaic Biological Power Sources for Implantable Devices**—Grant applications are sought to develop innovative, unconventional power sources to operate medical devices that are implanted inside the human body. The power sources could be biological or mechanical in design, and could include biomotion or *in vivo* biochemical reactions. Because current photovoltaic power sources contain metals and other highly toxic components, these sources must be carefully encased before implantation; therefore, the development of a small implantable biological power source would alleviate concerns about implantation safety and disposal. Grant applications must provide calculations to demonstrate that the proposed device will supply the energy required to power an implantable device and meet any biocompatibility requirements of the Food and Drug Administration. Some of the DOE national laboratories have developed considerable expertise in this research area and are available for possible collaboration.

Questions – Contact Dean Cole ([dean.cole@science.doe.gov](mailto:dean.cole@science.doe.gov))

**b. Radiopharmaceutical Development for Radiotracer Diagnosis and Targeted Molecular Therapy**—Grant applications are sought to develop: (1) radiolabeled compounds that could have applications as

## FY 2006 Topics

radiotracers for radionuclide imaging technologies such as positron emission tomography and single photon emission computed tomography; (2) improved and simplified production of radiolabeled compounds through the use of mini-accelerator technology or automated radiochemical analysis/synthesis techniques; and (3) radiopharmaceuticals for targeted molecular therapy. Of particular interest are radiochemical, synthetic, and combinatorial molecular engineering approaches. All efforts should ultimately result in a product for nuclear medicine use.

Questions – Contact Prem Srivastava ([prem.srivastava@science.doe.gov](mailto:prem.srivastava@science.doe.gov))

**c. Advanced Imaging Technologies**—Grant applications are sought for new, sensitive, high resolution instrumentation for radionuclide imaging. The instrumentation should advance the application of radiotracer methodologies for imaging molecular biological functions including cell communication and gene expression *in vivo*. Areas of interest include the development of: (1) new detector materials and detector arrays for both positron emission and single photon emission computed tomography; (2) software for rapid image data processing and image reconstruction; and (3) methods of integrating *in vitro* and *in vivo* instrumentation technologies for real time molecular imaging of biological function and for new drug development and utilization.

Questions – Contact Peter Kirchner ([peter.kirchner@science.doe.gov](mailto:peter.kirchner@science.doe.gov))

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## 11. CARBON CYCLE MEASUREMENTS OF THE ATMOSPHERE AND THE BIOSPHERE

Eighty-five percent of our nation's energy results from the burning of fossil fuels from vast reservoirs of coal, oil, and natural gas. These processes add carbon to the atmosphere, principally in the form of carbon dioxide (CO<sub>2</sub>). It is important to understand the fate of this excess CO<sub>2</sub> in the global carbon cycle in order to assess the terrestrial ecosystem response, the sensitivity of climate, and the potential for sequestration in natural carbon sinks of lands and oceans. Therefore, improved measurement approaches are needed to quantify carbon changes in components of the global carbon cycle, particularly the terrestrial biosphere, in order to improve understanding and assess the potential for future carbon sequestration.

A DOE working paper on carbon sequestration science and technology describes research needs and technology requirements for sequestering carbon by ocean and terrestrial systems (see Reference 1). This document calls for substantially improved technology for measuring carbon transformation of the atmosphere and biosphere. The document also describes advanced sensor technology and measurement approaches that are needed for detecting changes of carbon quantities of terrestrial (including biotic, microbial, and soil components) and oceanic systems, and for evaluating relationships between these carbon cycle components and the atmosphere.

Grant applications submitted to this topic should demonstrate performance characteristics of proposed measurement systems, and show a capability for deployment at field scales ranging from experimental plot size (meters to hectares of land – with comparable dimensions for marine systems) to nominal dimensions of ecosystems (hectares to square kilometers). Research to develop miniaturized sensors to determine atmospheric CO<sub>2</sub> concentration is also encouraged. In addition, Phase I projects must perform feasibility and/or field tests of proposed measurement systems to assure a high degree of reliability and robustness. Combinations of stationary remote and *in situ* approaches will be considered, and priority will be given to ideas/approaches for



## FY 2006 Topics

verifying biosphere carbon changes and for estimating carbon sequestration. Measurements using aircraft or balloon platforms must be explicitly linked to real-time ground-based measurements. Grant applications based on satellite remote sensing platforms are beyond the scope of this topic, and will be declined. **Grant applications are sought only in the following subtopics:**

**a. Sensors and Techniques for Measuring Terrestrial Carbon Sinks and Sources**—Measurement technology is required to quantify carbon sequestration by natural vegetation and ecosystems (i.e., carbon sinks) as well as CO<sub>2</sub> emissions to the atmosphere from natural or industrial sources. Grant applications are sought to develop sensors and unique measurement techniques (and associated system technology, if appropriate) to detect and quantify annual net carbon changes of terrestrial vegetation for large areas, or to measure and verify the magnitude of CO<sub>2</sub> emissions from various sources. For the measurement of CO<sub>2</sub> sinks, the sensor systems or new technology must be applicable for forests, grasslands, shrub lands, agricultural lands, and/or wetlands, and have the capability of producing spatially resolved aggregate estimates of terrestrial carbon changes to an accuracy of 10 to 25 g/m<sup>2</sup>/yr (or approximately 0.25 tonnes of carbon per hectare per year), with less than 25 percent uncertainty. For measuring emissions, the apparatus must be located at a point remote from the actual site of CO<sub>2</sub> release and provide accuracy estimates for CO<sub>2</sub> concentrations of approximately 0.5 ppm or less. Mechanical sensors must be durable in the full range of normal environmental conditions and exposures, including exposure to dust, rain, snow, heat, extreme cold, and fog. Operation in unattended, remote locations for weeks at a time, without degradation of the measurement, is also required; however, daily telecommunication with the system for monitoring performance and detecting potential operational problems would be desirable.

Proposed approaches, including both mechanical sensors and non-mechanical technology should consist of new, innovative methodologies that are significant advances over conventional scientific approaches used to measure CO<sub>2</sub>, carbon, and related compounds. Specifically, the measurement systems should be different from, or substantially augment, existing methods for eddy flux (covariance), routine monitoring of atmospheric CO<sub>2</sub> concentrations, or estimating carbon quantities of land and/or ocean constituents of the carbon cycle. Grant applications proposing *in situ* or in-stream measurement of flue gas emissions will be declined, as will applications that offer only incremental or marginal improvements over existing measurement systems.

Questions – Contact Roger Dahlman ([roger.dahlman@science.doe.gov](mailto:roger.dahlman@science.doe.gov))

**b. Novel Measurements of Carbon, CO<sub>2</sub>, and Trace Greenhouse Gas Constituents of Terrestrial and Atmospheric Media**—Improved measurement technology is needed to better characterize processes involving carbon transformations of soil, vegetation, and associated ecosystem components and exchanges with the atmosphere. Particular areas of interest include high resolution measurements of soil carbon/organic matter – i.e., the carbon content of biological tissues in various components (e.g., phytomass, detritus) of terrestrial ecosystems – as described in item (1) below; improved measurement technology for atmospheric CO<sub>2</sub>, as described in items (2) and (3) below; and high accuracy and precision measurement of other trace greenhouse gases as described in item (4) below.

(1) For determining the carbon content of biota and soil, grant applications are sought to develop and demonstrate measurement technology for estimating changes of carbon quantities and/or fluxes involving major components of ecosystems, with an accuracy on the order of 10 grams per square meter or less. Quantification of spatially resolved aggregate estimates of terrestrial carbon changes should have an accuracy of 10 to 25 g/m<sup>2</sup>/yr (or approximately 0.25 tonnes of carbon per hectare per year), with less than 25 percent uncertainty.

(2) Grant applications are sought to design and demonstrate a new CO<sub>2</sub> analyzer that: (a) can determine the mole fraction of CO<sub>2</sub> in dry ambient air to a relative precision of 1 part in 3000 or better in one minute or less; (b) operates with small amounts of gas (30 cc/min or less) to minimize problems due to water vapor and to

## FY 2006 Topics

minimize consumption of reference gases, if employed; (c) is robust enough for unattended field deployment for periods of half a year or longer; (d) costs less than \$5000 when manufactured in quantity; and (e) is not sensitive to motion.

(3) Grant applications are sought to develop instruments for measuring atmospheric CO<sub>2</sub>, lightweight (approximately 100 grams) sensors, which are capable of measuring fluctuations of CO<sub>2</sub> in air of the order of plus or minus 1 ppm in a background of 370 ppm. The devices must be suitable for launch on balloonsondes or similar such platforms, and therefore must be insensitive to large changes in ambient temperature and pressure. The devices also must be able to operate on low power (e.g., 9v battery), and have a response time of less than 30 seconds.

(4) Grant applications are also sought to develop new technology platforms that can be used to measure fluxes and/or concentrations of important trace greenhouse gas constituents and the isotopes of carbon, methane, CO, and other trace species. New instrumentation designs must have high potential for direct application for determining carbon, CO, and trace species sources and sinks. Also, design elements that ensure long-term and robust field deployment, should be included.

In general, new technology for measuring terrestrial biota and soil must be accomplished by *in situ* and/or non-invasive means and/or remote sensing of organic carbon forms across a range of temporal scales (from seconds to days) and spatial scales (from millimeters to kilometers), depending on the system properties being observed. Instruments must be portable and deployable in remote locations, and must not adversely impact the site of deployment. The term "remote sensing" means that the observation method is physically separated from the object of interest. Research that develops unique surface-based observations and uses them for the calibration/interpretation of other remotely derived data is of interest; however, except for the potential application of CO<sub>2</sub> sensors via balloonsonde, other methods of remote sensing data acquisition by airborne or satellite platforms will not be considered.

Questions – Contact Roger Dahlman ([roger.dahlman@science.doe.gov](mailto:roger.dahlman@science.doe.gov))

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## 12. BIOLOGICAL SOLUTIONS FOR REDUCING ATMOSPHERIC CARBON DIOXIDE AND FOR PRODUCING FUELS

The burning of fossil fuels adds carbon to the atmosphere, principally in the form of carbon dioxide, and the potential environmental impacts have made carbon management an international concern. There is increasing national and international interest in enhancing natural mechanisms to slow the rate of atmospheric CO<sub>2</sub> increase, or in developing new approaches to mitigate the current atmospheric rise in CO<sub>2</sub> levels. The U.S. Climate Change Technology Program [reference 9] calls for the development of biological approaches to remove CO<sub>2</sub> from the atmosphere in addition to energy production strategies that reduce or eliminate CO<sub>2</sub> emissions. A DOE report on carbon sequestration science and technology [6] describes research needs and technology requirements for sequestering carbon by aquatic and terrestrial systems, including a discussion of advanced biological processes and chemical approaches. Consequently, this topic addresses biological mechanisms that offer the potential to slow the rate of increase of atmospheric CO<sub>2</sub> by converting carbon into relatively stable organic or inorganic forms. For example, some terrestrial and aquatic plants might be studied

## FY 2006 Topics

for CO<sub>2</sub> conversion to biomass; other plants may be used to transform carbon into long-lived (refractory) organic compounds, thereby sequestering the CO<sub>2</sub> and slowing the rate of atmospheric increase.

Microbes can also make a significant contribution to the reduction of atmospheric carbon, as well as to the production of useful fuels. Some terrestrial microbes, found both in the subsurface and on the surface, have the potential to dramatically impact carbon sequestration, either directly or through their effects on plants. Other microbes can also be used in the production of hydrogen or other useful fuels. For example, the Genomes-to-Life (GTL) program is considering approaches to develop multiple cell functions into a single organism, or to form a microbial consortium for optimizing cellulosic transformation to ethanol.

Grant applications must provide for a systematic evaluation of proposed biological mechanisms for either carbon sequestration or fuel production systems. Estimates of the amount of CO<sub>2</sub> transformed or the fuel produced must be provided, and any assumptions concerning quantities and conditions for carbon fixation and sequestration or for fuel production must be clearly defined. (With regard to CO<sub>2</sub> transformation or fixation, proposed solutions must lead to the long term fixation and/or sequestration of large quantities of carbon – i.e., fractions of giga tonnes or more of carbon per year is considered significant). Feasibility tests (analytical, bench, or field) performed in Phase I must demonstrate that the proposed approach, when scaled up, could theoretically result in a meaningful rate reduction in atmospheric CO<sub>2</sub> concentration, significant amounts of carbon sequestered, or significant fuel production. Phase I should identify processes and mechanisms, and provide preliminary data on prospective rates and quantities of enhanced carbon transformation and sequestration or fuel production, with more comprehensive and peer-reviewed data sets developed in Phase II. Grant applications proposing only computer modeling without improvements in physical mechanisms or the enhancement of field approaches are not of interest and will be declined.

The facilities and expertise of the DOE Consortium for Research on Carbon Sequestration in Terrestrial Ecosystems (CSITE - <http://csite.esd.ornl.gov/>) can be made available to potential SBIR applicants to this topic. The CSITE is a consortium based at Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), and Argonne National Laboratory (ANL). The co-directors are Robin Graham (ORNL/email: [grahamrl@ornl.gov](mailto:grahamrl@ornl.gov)) and Blaine Metting (PNNL/email: [fb\\_metting@pnl.gov](mailto:fb_metting@pnl.gov)). Another useful resource is Applications of Biotechnology to Mitigation of Greenhouse Warming: Proceedings of the St. Michaels II Workshop, April 2003, available at: <http://www.battelle.org/bookstore/BookTemplate.aspx?ISBN=1-57477-141-8>. Also, scientists at Texas A&M University, Colorado State University, the University of Washington, North Carolina State University, and the Joanneum Research Institute in Austria can provide support to potential applicants. The DOE also supports carbon sequestration research at the National Energy Technology Laboratory (NETL). **Grant applications are sought only in the following subtopics:**

**a. Sequestration of Carbon by Plant-Soil and Aquatic Systems**—Virtually all plant species effectively capture CO<sub>2</sub> from the atmosphere and produce organic compounds, which sustain productivity of the Earth's ecosystems. Some of the fixed carbon is sequestered in soils or sediments and in wood products of terrestrial ecosystems. For example, woody species sequester carbon as lignocellulose, which is a stored product for the lifetime of the tree, and the below-ground productivity of many ecosystems is transformed into organic soil matter with intrinsically long residence times. Aquatic plants produce peat or organic-rich sediments. Grant applications are sought to identify and quantify the biological pathways and mechanisms leading to increased quantities of carbon sequestration by plant, soil (including soil microorganisms), and sediment components of terrestrial and aquatic ecosystems. Areas of particular interest include: (1) research on plant metabolic pathways or mechanisms that allow increased CO<sub>2</sub> fixation rates, achieved through conventional molecular or traditional genetic means, and leading to overall productivity increases; (2) novel technologies for managing vegetation and soils (such as cost-effective nutrient management, forest regeneration, ecosystem modification, and aquatic cultures) to enhance carbon uptake and retention, thereby significantly increasing CO<sub>2</sub> fixation and

## FY 2006 Topics

carbon (C) storage; (3) techniques for increasing the fraction of recalcitrant organic compounds produced during natural microbial conversion of plant biomass in soils, resulting in increased long-term C-storage (research with microbial components should focus on carbon and CO<sub>2</sub> reduction mechanisms, in contrast to oxidative pathways of organic matter transformations); and (4) measurement techniques that allow for the validation of technologies developed to enhance net long-term C sequestration in man-made and natural environments.

Grant applications should provide information about rates and quantities of carbon fixation or the enhancement of sequestration that the proposed technology can reasonably achieve. For terrestrial systems, proposed approaches should exhibit a capability to increase, or to measure increases of, carbon fixation or sequestration by at least 1 tonne per hectare per year. For rapidly C-fixing aquatic biosystems, the desired rate of consumption would be at least 5 grams of carbon (expressed on an atom basis) per gram cell dry weight per hour at ambient temperature (e.g., 15°C) conditions. Phase I must demonstrate the basic feasibility and efficacy of proposed sequestration mechanisms, with larger field-scale applications designed and tested in Phase II.

Questions – Contact Roger Dahlman ([roger.dahlman@science.doe.gov](mailto:roger.dahlman@science.doe.gov))

**b. Microbe-Based Carbon Sequestration in Harsh Environments**—Microbes exist in essentially every conceivable environment on Earth. In particular, the remarkable diversity and capabilities of microbes offer the possibility of developing novel microbe-based solutions for carbon sequestration in harsh environments (in contrast to the environments assumed in the previous subtopic). Therefore, grant applications are sought to demonstrate and quantify terrestrial, photosynthetic, microbe-based strategies to increase the carbon sequestration potential in harsh environments, such as deserts or brackish water. Field studies are not necessarily expected and should not be proposed without appropriate NEPA (the National Environmental Policy Act) approval.

Questions – Contact Jeffrey Amthor ([jeff.amthor@science.doe.gov](mailto:jeff.amthor@science.doe.gov))

**c. Microbe-Based Hydrogen Production**—Biotechnology offers the promise of capitalizing on the natural capabilities found in the microbial world to produce new fuels, leading to a reduction in green house gas emissions. In particular, many microbes have the ability to produce hydrogen under particular conditions. Therefore, grant applications are sought to demonstrate and quantify: (1) microbe-based hydrogen production reactors, or (2) high-throughput assays for assessing and quantifying the production of microbe-based hydrogen in experimental reactors.

Questions – Contact John Houghton ([john.houghton@science.doe.gov](mailto:john.houghton@science.doe.gov))

**d. Application of Genomes-to-Life (GTL) Concepts to Cellulosic Ethanol Production**—In the conversion of cellulosic material to ethanol, a more complete understanding is needed of the enzymes and microbes involved, in order to overcome inefficiencies in current production processes. Grant applications are sought to take advantage of advances in GTL science, as well as in systems biology, that will simplify and consolidate the conversion of cellulose to ethanol. Emphasis should be placed on developing process improvements from externally generated, biologically-derived catalysts; single organisms; and/or integrated microbial systems composed of a stable consortium of organisms. Approaches of interest include improving the pretreatment of lignocellulosic material for saccharification and developing organisms that (1) thrive in optimal bioreactor temperatures and pH environments; (2) ferment both C5 and C6 sugars; and (3) catalyze products in spite of inhibitors, including high concentrations of ethanol. Proposed research would be expected to coordinate with the research goals described in the DOE GTL Roadmap [11].

Questions – Contact John Houghton ([john.houghton@science.doe.gov](mailto:john.houghton@science.doe.gov))



## FY 2006 Topics

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## PROGRAM AREA OVERVIEW OFFICE OF FOSSIL ENERGY

Fossil energy plays a key role in our Nation's prosperity, and it is important that we secure an adequate energy supply from our coal, natural gas, and oil resources. However, national complacency, derived from low-cost imported oil, has allowed petroleum imports to increase to alarming levels. We need not go far back in history to find out how uncertainty in petroleum supply can affect our Nation's economic growth. Nonetheless, our

## FY 2006 Topics

near term power generation, heating, and transportation needs still require the utilization of these hydrocarbon-based fuels. As the economy expands, demand for hydrocarbons will increase accordingly. Therefore, the Office of Fossil Energy seeks to develop advanced fossil energy technologies that are environmentally sound and economically competitive.

Technological innovation is required to take advantage of the United States' large supply of coal and natural gas reserves. Coal's major drawback is that it contains sulfur, nitrogen, mercury, and other trace heavy metals, precursors of pollutants that could have deleterious effects on the environment. Also, natural gas is produced with a wide variety of pollutant-forming compounds, which preclude some applications such as fuel cells. For both coal and natural gas, further improvements are needed to develop advanced, low cost, high-efficiency processes for the production of clean energy. In addition, it is prudent to consider ways to reduce carbon dioxide and other greenhouse gases that are generated by the combustion of fossil fuels, to investigate carbon sequestration in geological and other systems, to consider hydrogen as alternate fuel, and to mitigate impacts on water resources. Advanced technology development in materials that assure compatibility with advances in power systems – as well as innovations in fuel cells, measurements, sensors, monitors, and controls – will be needed for these technologies to be commercially competitive.

Improvements are also needed in our ability to recover both oil and natural gas. About two-thirds of our national petroleum reserve is "unrecoverable"; i.e., it cannot be extracted economically by conventional means. This unused resource could play a major role in supplementing the national petroleum supply if efficient approaches were developed for improved extraction. Natural gas production and utilization could also be increased through improved characterization of reserves and through better infrastructure.

The following topics seek the participation of small businesses in addressing problems related to utilization of coal and natural gas to produce power, and to the recovery of oil and natural gas. Many of the topic offerings indirectly support the DOE's FutureGen initiative, a program to demonstrate hydrogen production and carbon sequestration. The objectives of FutureGen are to produce hydrogen at \$4/MMBtu, sequester 100% of the carbon-dioxide, and produce electricity with zero emissions at less than a 10% increase in cost.

For additional information regarding the Office of Fossil Energy priorities, [click here](#).

### 13. CAPTURE AND SEQUESTRATION OF CARBON

The world is becoming increasingly concerned about the greenhouse effect. Hence, the capture and permanent sequestration of CO<sub>2</sub>, as well as other non-CO<sub>2</sub> greenhouse gases (GHG), has become a major world wide goal. In the United States, the capture and sequestration of CO<sub>2</sub> and other non-CO<sub>2</sub> GHG is expected to be an important element of any strategy to reduce the emission of GHG to the atmosphere. **Grant applications are sought only in the following subtopics:**

**a. Advanced Technologies for Monitoring, Mitigation, and Verification**—Monitoring, mitigation, and verification (MM&V) is defined as the capability to measure the amount of CO<sub>2</sub> stored at a specific sequestration site, monitor the site for leaks or other deterioration of storage integrity over time, and verify that the CO<sub>2</sub> is stored in a way that is permanent and not harmful to the host ecosystem. MM&V technologies are sought for the geologic subsurface, the geologic surface, and terrestrial sequestration applications.

For MM&V related to geologic subsurface sequestration, grant applications are sought for technologies/approaches to track the fate of CO<sub>2</sub> within the geologic formations underlying the earth, and to identify the possible migration of CO<sub>2</sub> to the surface and potential leaks at the surface. Approaches of interest include surface-to-borehole seismic, micro-seismic, and cross-well electromagnetic technologies; electrical

## FY 2006 Topics

resistance tomography; CO<sub>2</sub> tracers; surface leak detection; and mineralization concepts for leakage mitigation. For these subsurface technologies, the resolution should be sufficient to allow the detection of 500 metric tons of injected CO<sub>2</sub>.

For MM&V related to geologic surfaces, grant applications are sought to develop technologies/approaches for monitoring surface leaks above a geologic formation where CO<sub>2</sub> has been injected. Surface detection systems must be able to differentiate stored carbon from natural biological systems and measure variations in carbon of no less than 0.5 ppm CO<sub>2</sub>. Approaches of interest may consist of an open path detection system or a network of gas collection systems. Proposed solutions should be remote systems capable of continuous operation, remote control and data acquisition, and of rugged design to withstand the elements.

For MM&V related to terrestrial sequestration, grant applications are sought for low cost technologies that are capable of measuring carbon at one-tenth of the cost and time now required to analyze samples with current methods. Proposed systems must have a minimum detection limit of 0.1 percent carbon in soil, with an accuracy and precision of measurement of  $\pm 10\%$ . Soil carbon must be measured at a minimum within the top 30 cm, with measurements at 100 cm below the surface desired. Proposed systems may utilize either *in situ* measurements or soil sampling (soil core) techniques for rapid field analysis.

Questions – Contact John Litynski ([john.litynski@netl.doe.gov](mailto:john.litynski@netl.doe.gov))

**b. Advanced Separation and Capture Techniques for CO<sub>2</sub>**—Significant research and development is currently being pursued for new technologies to separate and capture CO<sub>2</sub> from flue gas streams produced by existing coal-fired electric generating power plants. Aqueous amine absorption is the state-of-the-art technology for post-combustion CO<sub>2</sub> capture from flue gas. However, amine absorption has a number of drawbacks, including significant capital and operating costs. Therefore, grant applications are sought to develop technologies that can substantially lower the cost of CO<sub>2</sub> capture from flue gas produced by existing coal-fired power plants. Approaches of interest include new methods to improve the performance and lower the costs of absorption technologies, as well as the development of alternative techniques that make use of CO<sub>2</sub> sorbents, nanoscale materials as separation agents, membranes, and other separation processes. The research effort should demonstrate the viability of the technology to perform with actual flue gas compositions generated from existing coal-fired power plants. Technologies should be capable of 90% or greater reduction in CO<sub>2</sub> emissions per net kWh and result in less than a 20% increase in the cost of energy services. Systems and economic analyses should be performed in accordance with the

National Energy Technology Laboratory's Carbon Capture and Sequestration Systems Analysis Guidelines (<http://www.netl.doe.gov/coal/Carbon%20Sequestration/pubs/CO2CaptureGuidelines.pdf>). Grant applications should demonstrate familiarity with both current commercial technologies and ongoing research.

Questions – Contact Jose Figueroa ([jose.figueroa@netl.doe.gov](mailto:jose.figueroa@netl.doe.gov))

**c. Non-Carbon Dioxide (Non-CO<sub>2</sub>) Greenhouse Gas Reduction**—Because non-CO<sub>2</sub> greenhouse gases (e.g., methane [CH<sub>4</sub>], nitrous oxide [N<sub>2</sub>O]) can have significant economic value, emissions can often be captured or avoided at relatively low net cost. In particular, the DOE's Carbon Sequestration Program focuses on fugitive CH<sub>4</sub> emissions where non-CO<sub>2</sub> greenhouse gas abatement is integrated with energy production, conversion, and use. Landfill gases and coal mine methane gas are two priority opportunities. Therefore, grant applications are sought to develop technology that could significantly reduce the escape to the atmosphere of CH<sub>4</sub> and N<sub>2</sub>O, from landfill gases and coal mine methane. For landfill gas, areas of interest include the control of CH<sub>4</sub>/N<sub>2</sub>O generation, CH<sub>4</sub>/CO<sub>2</sub> separation, bacterial oxidation of CH<sub>4</sub> and N<sub>2</sub>O, and the use of landfill gas for enhanced-coalbed-methane recovery. For coal mine methane, areas of interest include the separation of methane in air at concentrations of 0.3-1.5 vol% and the catalytic oxidation of methane in air at concentrations of 0.3-1.5 vol%.

## FY 2006 Topics

Questions – Contact Charles Byrer ([charles.byrer@netl.doe.gov](mailto:charles.byrer@netl.doe.gov))

**d. Risk Assessment for Geologic Sequestration**—Geologic sequestration is being evaluated as a viable means of long-term CO<sub>2</sub> storage and climate change mitigation. It is estimated that geologic storage will hold hundreds to thousands of gigatons of CO<sub>2</sub>. The accurate assessment of risks will be fundamental to public acceptance and ultimate deployment of geologic sequestration. Therefore, grant applications are sought to develop risk assessment methodologies and simulation models that can be used to quantify and mitigate accidental releases of CO<sub>2</sub> stored in geologic sequestration sites. Sequestration sites of interest include unmineable coal seams, saline formations, and depleted oil and gas reservoirs. Proposed approaches should be capable of identifying and describing global, operational, and local risks, and various scenarios should be analyzed. Grant applications should address standards and protocols for measurement, mitigation, and verification, which satisfy various current and probable environmental requirements, and also should address issues related to safety, leaks, and responsibility.

Questions – Contact Dawn Deel ([dawn.deel@netl.doe.gov](mailto:dawn.deel@netl.doe.gov))

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#### Subtopic a: Advanced Technologies for Monitoring, Mitigation, and Verification

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3. *Soil Survey Laboratory Methods Manual—The Soil Survey Analytical Continuum: Soil Survey Investigations Report No. 42 – Version 3.0*, U.S. Department of Agriculture-National Resources Conservation Service/National Soil Survey Center, January 1996. (Full text available at: [ftp://ftp-fc.sc.egov.usda.gov/NSSC/Lab\\_Methods\\_Manual/ssir42.pdf](ftp://ftp-fc.sc.egov.usda.gov/NSSC/Lab_Methods_Manual/ssir42.pdf))

#### Subtopic b: Advanced Separation and Capture Techniques for CO<sub>2</sub>

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## FY 2006 Topics

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## 14. ENVIRONMENTAL TECHNOLOGY INNOVATIONS AND CONTROLS FOR FOSSIL ENERGY FACILITIES

The use of coal in energy utilization and conversion systems suffers from a number of considerations with respect to the fuel itself. Coal is a solid fuel containing components that are precursors of environmental pollutants or materials that are potentially damaging to downstream components. Further, coal contains mineral



## FY 2006 Topics

matter that is converted into ash, which can lead to suspended particulates in air, erosion of or deposition in downstream components, and problems of solid waste disposal. This topic seeks to mitigate the environmental disadvantages of coal utilization, including its potential impact on water quality and availability, through improvements in various aspects of the coal utilization cycle. The research is expected to provide high-quality scientific information on present and emerging environmental issues for use in regulatory and policy decision-making. Environmental considerations and the concomitant need for low-cost compliance options are the primary drivers of the current research program.

In addition, this topic addresses the development of robust sensor networks for coal power systems, using instrumentation that can withstand the harsh conditions of advanced power generation systems. **Grant applications are solicited only in the following subtopics:**

**a. Economical Sorbents for Mercury Removal from Coal-Fired Power Plants**—On March 15, 2005, the Environmental Protection Agency (EPA) issued the Clean Air Mercury Rule to permanently cap and reduce mercury emissions from coal-fired power plants. When fully implemented, these rules will reduce utility emissions of mercury from 48 tons a year to 15 tons, a reduction of nearly 70 percent. The Clean Air Mercury Rule establishes “standards of performance” that limit mercury emissions from new and existing coal-fired power plants and creates a market-based cap-and-trade program that will reduce nationwide utility emissions of mercury. New coal-fired power plants (i.e., where construction started on or after Jan. 30, 2004) will have to meet stringent new source performance standards in addition to being subject to the caps.  
(<http://www.epa.gov/air/mercuryrule/index.htm>)

The DOE’s National Energy Technology Laboratory (NETL) currently manages the largest research program in the country for controlling coal-based mercury emissions.  
(<http://www.netl.doe.gov/coal/E&WR/mercury/index.html>) The determination of cost-effective mercury control strategies is complex and highly coal and plant specific. However, one particular technology has the potential for widespread application: the injection of activated carbon upstream of either an electrostatic precipitator (ESP) or a fabric filter baghouse. This technology has potential application to the control of mercury emissions in plants that are not equipped with flue-gas desulfurization scrubbers, which includes 75% of all U.S. plants. Unfortunately, one of the main barriers to the use of this technology is the cost of sorbents, which represent a large fraction of the overall cost, especially for units equipped with ESPs. In order to make sorbent injection for mercury removal more cost effective, it is necessary to either reduce the amount of sorbent needed or decrease the cost of sorbent production. NETL has researched the economics and performance of novel sorbents and demonstrated that there are alternatives to the commercial standard.  
([http://www.netl.doe.gov/coal/E&WR/mercury/control-tech/pubs/Final%20Report%20for%20DE-FC26-01NT41180\\_DOENETL\\_Apogee%20Scientific.pdf](http://www.netl.doe.gov/coal/E&WR/mercury/control-tech/pubs/Final%20Report%20for%20DE-FC26-01NT41180_DOENETL_Apogee%20Scientific.pdf))

Grant applications are sought to develop lower price mercury sorbents for power generation customers. The research effort must provide evidence that the cost of removing mercury will be at least 25% less than that of the baseline cost, \$60,000 per pound of mercury removed (a cost that includes not only the cost for producing the sorbent, but also the cost of transportation, handling, feeding, and waste handling). In addition, procedures must be described to evaluate the effectiveness of the proposed sorbent for mercury removal. Although bench-scale, fixed-bed adsorption tests can provide an understanding of factors that affect mercury adsorption, as well as a relative ranking of performance for different sorbents, laboratory results alone cannot predict how well the sorbent will remove mercury in a full-scale system.

Questions – Contact Robert Patton ([robert.patton@netl.doe.gov](mailto:robert.patton@netl.doe.gov))

**b. Water Usage in Electric Power Production**—Power generated from fossil fuels is dependent on water. On average, approximately 21 gallons of water are required for each kWh of power produced. Thermoelectric

## FY 2006 Topics

power production uses approximately 195 billions of gallons of water per day. In power generation, the largest single use of water is for cooling the low-pressure steam from the turbine. Under the Clean Water Act, section 316(b), the EPA has developed new regulations to reduce this cooling usage of water and improve cooling water intake structures. Research opportunities exist for reducing or eliminating the need to use water for cooling purposes. Air has been considered as an alternative, but air-cooled systems (sometimes referred to as dry systems) can have associated capital-cost and energy-inefficiency penalties, particularly in retrofit applications. Non-potable water is another option for cooling purposes, but there may be negative impacts on existing cooling towers. Other water-related issues associated with power plants involve their wastewater streams, including cooling tower blow-down water and flue gas desulphurization wastewater; these waste streams are often large volume, low concentration waters that are expensive to treat on a per-contaminant basis. Therefore, grant applications are sought to identify novel concepts and technologies to reduce both the amount of water used in coal power generation and the potential impact on water quality. Grant applications must be directed toward one of the following areas of interest: (1) reducing the amount of water used in power generation, (2) water quality improvements in power generation, (3) improvements in wet or dry cooling towers, (4) novel, low-cost treatment technology to allow for the use of wastewater as process water in power plants, or (5) novel, low-cost treatment technologies for power plant wastewater.

Questions – Contact Barbara Carney ([barbara.carney@netl.doe.gov](mailto:barbara.carney@netl.doe.gov))

**c. High Volume Utilization of Coal Combustion By-Products**—More than half of the electricity generated in the U.S. is produced by coal-fired facilities. In January of 2004, the EPA published draft regulations to control mercury emissions from coal-fired electric utilities. One of the proposed technologies to control mercury involves the addition of activated carbon to the flue gas. The activated carbon would be collected with the fly ash via electrostatic precipitators or fabric filters. Currently, fly ash is considered a non-hazardous material for disposal; however, the increased levels of mercury, from the addition of the mercury-impregnated activated carbon, could change this status. Preliminary research suggests that the addition of activated carbon to the fly ash could make the fly ash unmarketable or increase the cost of disposal. Simultaneously, the EPA published another draft regulation that targets both sulfur dioxide and nitrogen oxide emissions from power plants. To comply with this regulation, it is anticipated that more units will be equipped with flue gas desulfurization (FGD) technology. In fact, FGD production in the U.S. may increase by an order of magnitude to almost 200 million tons, thus exceeding the production of all other coal combustion products.

In the wake of these regulations, grant applications are sought to: (1) develop novel high volume utilization technologies for fly ash that contain very high concentrations of either unburned or activated carbon from mercury control technologies, and (2) develop high volume utilization technologies of flue gas desulfurization materials in novel applications (excluding wallboard production).

Questions – Contact Robert Patton ([robert.patton@netl.doe.gov](mailto:robert.patton@netl.doe.gov))

**d. Development of Robust Sensor Networks for Intelligent Control of Advanced Power Generation Systems**—Significant technological advancements are being made towards the development of near-zero-emission, coal-based power plants that are based on high efficiency technologies. Efforts have been initiated to develop and incorporate intelligent control strategies for these emerging technologies. Effective control systems will be critical to the operation and integration of advanced power generation and will contribute to the efficiency, environmental performance, and cost reductions for new installations.

A layered control strategy is the envisioned approach for control systems development. The basic and safety control layer will remain as a highly-reliable redundant communication system, followed by the incorporation of advanced control, communication, sensor networking and data management tools for system optimization and preventative maintenance. Bus-type platforms are viewed as important for reducing the cost of control

## FY 2006 Topics

systems, as well as for providing an opportunity to incorporate new sensor technologies with “smart” sensing capabilities. The incorporation of wireless sensor networks for system optimization or condition monitoring also is of interest. Finally, standardized communication platforms, on which robust sensor networks can be created, are viewed as important for minimizing costs and for industry acceptance.

Grant applications are sought for the design and development of sensor networks for the advanced control of select components or systems within an advanced coal-based power generation plant, including air separation units, gasification, syngas/exhaust gas cleanup, and turbine/solid-oxide-fuel-cell hybrid systems. Descriptions of the power systems can be found on the National Energy Technology Laboratory’s (NETL) website ([www.netl.doe.gov](http://www.netl.doe.gov)). Proposed sensor networks should include the use of physical and chemical sensors that can operate in harsh environments, as well as sensors that operate at more benign conditions, to provide real time diagnostic capabilities. (Note that much of the plant environment is National Electrical Manufacturers’ Association (NEMA) Class I Division II hazardous location.) Grant applications also should (1) describe the type and limitations of the actuation methodology to be used in control loops; and (2) outline the anticipated performance, cost, and efficiency benefits that should be expected. Approaches that use traditional proportional, integral, derivative (PID) control technology are not of interest.

Questions – Contact Susan Maley ([susan.maley@netl.doe.gov](mailto:susan.maley@netl.doe.gov))

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### Subtopic b: Water Usage in Electric Power Production

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## FY 2006 Topics

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## 15. SOLID OXIDE FUEL CELL (SOFC) BALANCE-OF-PLANT (BOP)

The goal of the DOE-sponsored Solid State Energy Conversion Alliance (SECA) is to develop commercially-viable (\$400/kW) 3 to 10 kW SOFC power generation systems by 2010. SOFC power generation systems provide significant advantages over current technologies in diverse stationary, mobile, and military applications. SOFC systems are very efficient, from 40 to 60 percent in small systems and up to 85 percent in larger co-generation applications. The electrochemical conversion in a SOFC takes place at a lower temperature (650°C to 850°C) than combustion-based technologies, resulting in decreased emissions – particularly nitrogen oxides, sulfur oxides, and particulate matter. In addition, SOFC systems offer fuel flexibility, as they are compatible with conventional fuels such as hydrogen, coal, natural gas, gasoline or diesel. This topic seeks advances in key balance-of-plant (BOP) component design in support of the SECA Program goal. **Grant applications are sought only in the following subtopics:**

**a. Low-Cost High-Efficiency Cathode Air Blowers**—SOFC systems require blowers to provide motive force to incoming atmospheric air, in order to overcome the pressure drop in the various valves and heat exchangers, and in the fuel cell stack. The energy required to drive this component is typically one of the largest parasitic loads for the SOFC system; consequently, high blower efficiency is paramount to high system efficiency. Furthermore, blower reliability is critical to ensure safe long-term system operation. Grant applications are sought for the design and development of motor-driven blowers for 3 to 10 kW SOFC systems, with cost, efficiency, and reliability—the critical factors for meeting the SECA Program goal. Specific blower performance specifications are dependent upon the design of the SOFC system with which it is associated; nevertheless, the following representative nominal requirements, in lieu of design-specific data, should be addressed within the grant application: (1) use of atmospheric air (inlet) as the working fluid; (2) pressure ratio approximately 1.1 to 1.2, at a peak airflow of 1500 standard liters per minute; (3) capability for variable speed control with a turn-down ratio of at least 5:1; (4) overall efficiency of at least 60% under the aforementioned operating conditions – high part-load efficiency is also desired; (5) a design life of 40,000 hours, with a 100% duty cycle and 10,000 hour maintenance interval; (6) a target cost less than \$100 per unit, based upon a production volume of 50,000 units per year – costs should be estimated and justified; and (7) noise less than 70

## FY 2006 Topics

dBa. In addition, the issue of contamination of the process air (e.g., from the introduction of grease or oil) must be addressed, as the introduction of foreign matter may have an adverse effect on the SOFC cathode.

Questions – Contact Travis Shultz ([travis.shultz@netl.doe.gov](mailto:travis.shultz@netl.doe.gov))

**b. Low-Cost High-Temperature Heat Exchangers**—Grant applications are sought to develop novel, high-temperature heat exchanger designs for cost-effective cathode air pre-heaters for use in 3 to 10 kW SOFC systems. For this component, the source-side working fluid will be post-combustor SOFC stack effluent, with an inlet temperature between 800°C and 1000°C. The sink side fluid will be air from the cathode air blower with a temperature as low as 30°C, depending upon the particular system design. Maximum source and sink side flow rates are approximately 1500 standard liters per minute. Due to the parasitic losses associated with the cathode air blower and the resultant adverse impact upon system efficiency, this heat exchanger requires a very low differential pressure drop (1.5 to 2.5 kPa on the sink side; 0.75 to 1.25 kPa on the source side) and high effectiveness ( $\approx 85$  to 90%). The proposed heat exchanger design must have a design life of 40,000 hours, with a 100% duty cycle and 10,000 hour maintenance interval. The unit must be able to tolerate at least 30 thermal cycles, between operating and room temperatures, over its design life.

Although material sets such as nickel-based superalloys (e.g., 600 series Inconels) are currently being used for the heat exchangers, these materials and the required fabrication processes are very expensive. Regardless of the proposed design, grant applications must address the following issues with respect to the choice of materials: cost, reliability (including tolerance to high steady-state temperatures, internal temperature gradients, and thermal cycles), and manufacturability. Also, materials identified for incorporation into the design must be analyzed for chemical stability (e.g., resistance to corrosion and sulfidation attack) and thermo-mechanical stability (e.g., creep, thermal shock tolerance) in the context of the proposed design and application. Ceramic materials will be considered, provided that any thermal shock and leakage (at manifold interfaces or working fluid crossover) issues can be adequately addressed. The unit manufactured cost, based upon a production volume of 50,000 units per year, should be estimated and justified.

Questions – Contact Magda Rivera ([magda.rivera@netl.doe.gov](mailto:magda.rivera@netl.doe.gov))

**c. DC-AC Inverter with Reactive-Power-Management Functionality**—Fuel cell systems with inverters that provide reactive-power-management functionality can support industrial and commercial facility needs for reactive power and harmonic current. In addition, fuel cell systems equipped with such inverter capabilities also can support utility distribution-circuit reactive power flows, with the greatest benefit realized for heavily-loaded distribution circuits. Reactive power current and voltage phase displacement correction would be a value-added function to the utility, provided that the fuel cell plant could be: made available for use and dispatched when needed; deployed at location(s) where reactive power is needed within the circuit; and sized or aggregated at power ratings sufficient to satisfy the active and reactive power needs. Fuel cell systems with inverters capable of providing reactive power support could: (1) provide greater flexibility in delivering various current wave forms, as needed, compared to fuel cell systems without such inverter features; (2) reduce the power generation capacity needed to support minimum voltage levels when the fuel cell is operating as a voltage source (e.g., stand-alone operation, supplying power to individual facilities); and (3) help reduce distribution circuit current levels and enable utilities to deliver greater amounts of active power to customers – a benefit that could help defer the expense of investing in distribution circuit upgrades.

Grant applications are sought to design and develop an inverter suitable for converting direct current produced by solid oxide fuel cell stacks into 60Hz alternating current with the following minimum requirements: (1) reactive power capability of 0.6 to unit power factor at 100% rated active power output; (2) DC to AC energy conversion efficiency greater than or equal to 95%; (3) a modular and scalable design suitable for high-volume mass-production; (4) output of 12.47 KVAC, with a scalable design for varied current rating applications and



## FY 2006 Topics

suitable for converting up to 5 MW of active power; (5) high reliability with availability greater than or equal to 99.9%; (6) long service life, greater than or equal to 10 years; (7) autonomous/semi-autonomous control to aid in the support of power quality requirements (i.e., voltage and frequency control, and reactive power and harmonic current load requirements) in various applications (e.g., industrial and commercial facilities, and the utility distribution circuit); and (8) communication and control capabilities to enable utility interface for dispatch requests. When mass-produced in quantities greater than 50,000 modules per year, the inverter production cost should not exceed \$100/kW. During Phase I, it is expected that a detailed design will be developed and appropriate lab-scale tests will be performed to demonstrate innovative features. In addition, a detailed cost estimate should be prepared, in order to substantiate high-volume production cost projections.

Questions – Contact Donald Collins ([donald.collins@netl.doe.gov](mailto:donald.collins@netl.doe.gov))

**d. Novel Energy Storage Devices**—Distributed generation applications (e.g., in residences) for SECA-class SOFC power generation systems will be characterized by highly variable electrical loads; consequently, performance- and cost-optimized SOFC systems for these applications will require energy storage devices to meet peak load demand, as well as loads that fall below the minimum practical turndown of the fuel cell. In addition, the energy storage device must act to maintain line voltage during step changes in load, thereby reducing any deleterious impact of load transients on SOFC system components. Lastly, on-board energy storage systems must allow for the controlled shutdown of powered systems and loads in the event of a SOFC system casualty (e.g., an unexpected loss of fuel supply).

Grant applications are sought for the research and development of novel low-cost energy storage devices for incorporation into 3 to 10 kW SOFC systems. Proposed approaches for the high-temperature SOFC systems should consider the integration of technologies that utilize high-temperature fuel cell architectures. Proposed solutions should: (1) be able to provide 1.5 to 3 kW to load over a period of one hour (1.5 to 3 kW-h of usable energy storage); (2) have a lifetime of at least 5000 charge-discharge cycles; and (3) have a volumetric energy density greater than 150 W-h/liter. When integrated with the power electronics of SOFC systems, the energy storage technologies must be capable of achieving a manufactured cost less than \$300 per kW-h of usable capacity, including packaging and controls (“usable” means that the cost per kW-h is adjusted for the allowable depth-of-discharge, in order to achieve the 5000-cycle life) in high-volume production (100,000 units/year). Finally, the high-volume cost should be estimated and justified.

Questions – Contact Heather Quedenfeld ([heather.quedenfeld@netl.doe.gov](mailto:heather.quedenfeld@netl.doe.gov))

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### Subtopic c: DC-AC Inverter with Reactive-Power-Management Functionality

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## 16. COAL GASIFICATION AND COMBUSTION TECHNOLOGIES

Coal gasification offers a versatile and clean way to convert the energy content of coal into electricity, hydrogen, other high quality transportation fuels, as well as high-value chemicals to meet specific market

## FY 2006 Topics

needs. Most importantly, in a time of electricity and fuel price spikes, flexible gasification systems can provide a capability to operate on low-cost, widely-available feedstocks. Furthermore, gasification may be one of the best ways to produce clean-burning hydrogen for tomorrow's automobiles and power-generating fuel cells. Hydrogen and other coal-derived gases also can be used to fuel power-generating turbines or used as chemical "building blocks" for a wide range of commercial products. The DOE Office of Fossil Energy is working on coal gasifier technology advances that enhance efficiency, environmental performance, and reliability.

In addition, new materials, ideas, and concepts are required to significantly improve performance and reduce the costs of existing fossil systems or to enable the development of new systems and capabilities. The Fossil Energy Materials Program conducts research and development on high-performance materials for longer-term fossil energy applications, including gas separations and storage. The program is concerned with operation in the hostile conditions created when fossil fuels are converted to energy. These conditions include high temperatures, elevated pressures, and corrosive environments (reducing conditions, gaseous alkali). **Grant applications are sought only for the following subtopics:**

**a. Novel Concepts in Gasification**—Natural gas is used as a feedstock in many industries in addition to the power production industry. However, the increasing cost of natural gas, along with the likelihood that the cost will continue to increase, is driving the development of new technologies to improve the economic return for coal gasification processes outside power production. Therefore, grant applications are sought to develop novel technologies to make gasification, from a feedstock of at least 75% coal, more attractive for industrial use, including the production of hydrogen or methane. Target industries include small utility, metals, chemicals, pulp and paper, and glass. Proposed approaches should demonstrate a significant impact on the chosen industry or industries – the larger the niche for the gasification process, the better. Small niche and/or limited location processes are not of interest unless the economic impact is significant in spite of these restrictions. The proposed novel technology and overall process may be for either near term or long term deployment into industry. DOE envisions that the annual market for industrial applications would be in the 25 to 100 MWe equivalent range.

Grant applications must address optimizing the operating conditions for a specific industrial application. For example, for hydrogen/methane production, the operating conditions and design characteristics that might reasonably be expected to influence the methane and/or hydrogen content include: pressure; temperature; feed media and system (dry vs. wet slurry with water); residence time and internal or external recirculation/recycle rates; sizing of reaction chamber; feed rates of oxidant or steam; ash content and slagging temperature; particle sizing; feed injector mixing patterns; syngas cooling and quench; number and design of gasification stages; internal/external shift reaction catalysts; and internal separation mechanisms, such as sorbents and/or membranes. Process operating conditions that can offer potential advantages in efficiency and cost are preferred, and an assessment of these factors should be included as part of the data evaluation component of the research project.

Grant applications must also: (1) define the products of the gasification process and show whether they will be exported, used within the plant, or a combination of each – it is not necessary for power to be one of the products, although it may be; (2) consider options that can be adapted for use in existing types of gasifier systems – development of wholly new gasifier systems is not of interest; and (3) include in Phase I an analysis of projected plant savings and a description of the market for exported products (in terms of size, expected rate of growth or loss, and competing processes or mitigating circumstances). Finally, limited modeling to support experimental work is acceptable, but grant applications that involve extended, idealistic modeling of gasification systems, without supporting experimental data, are not of interest.

Questions – Contact Jenny Tennant ([jenny.tennant@netl.doe.gov](mailto:jenny.tennant@netl.doe.gov))

## FY 2006 Topics

**b. Novel Concepts in Air Separation (Non-Cryogenic; Non-Membrane)**—Oxygen is the third largest commodity chemical in the U.S., with an annual market over \$2B. However, the high cost of oxygen has been a barrier to the widespread application of oxygen-enriched combustion and oxygen-blown gasification in coal-fired power plants. A lower cost of oxygen would allow a significant market growth for oxygen, leading to greater productivity, efficiency, and environmental improvements of power plants and other oxygen-intensive industries. Grant applications are sought to develop new concepts for the non-cryogenic, non-membrane separation of oxygen from air at temperatures ranging from ambient to 900°C. The oxygen product must be higher than ambient pressure – in fact, pressures closer to pressure inside a gasifier (typically at least 400 psi) are preferred, as high pressures would reduce the cost of feeding the oxygen to the gasifier. Grant applications must describe: (1) the potential economic advantage of the proposed technology over conventional cryogenic and membrane air separation processes; and (2) the advantage of integrating the proposed oxygen separation technology with an IGCC and/or gasification-based hydrogen production process.

Questions – Contact Arun Bose ([arun.bose@netl.doe.gov](mailto:arun.bose@netl.doe.gov))

**c. Hydrogen Production and Storage**—The DOE's FutureGen project, now in its early planning stage, aims to demonstrate the technical/economical feasibility of a coal gasification plant to produce power, with near-zero emissions including the emission of carbon dioxide. The strategy is to convert coal to hydrogen that would be used as fuel for fuel cells and/or gas turbines, with the concurrent sequestering of the concentrated carbon dioxide from the processing and power blocks. Under this scheme, coal first would be gasified to produce synthesis gas (mainly hydrogen and carbon monoxide). This would be followed by processes for removing impurities and converting hydrogen through the water-gas-shift reaction. Finally, the hydrogen would be separated from other compounds.

The efficiency of the coal-to-hydrogen plant could be enhanced if the downstream steps of water-gas-shift and hydrogen separation were combined into a single step, carried out at temperatures compatible with the synthesis gas that exits from the cleanup step. (Current development work shows that clean syngas can be produced in the 350°C to 400°C range.) Therefore, grant applications are sought to develop new hydrogen separation/purification concepts, which can operate in the preferred 350°C to 400°C range, as a first step in the development of a combined water-gas-shift and hydrogen separation reactor. Proposed approaches should provide robust performance; high hydrogen throughput, selectivity, and recovery; long system life; and low operating cost. These new technologies should be able to operate at pressures compatible with gasifier pressures up to 1000 psig. In addition, they should have high tolerance for the low levels of sulfur that are present in feed gas. Grant applications should demonstrate familiarity with current commercial technologies to produce hydrogen from coal, as well as with the ongoing R&D supported by DOE in the coal-to-hydrogen program.

Grant applications are also sought to develop improved hydrogen separation membranes for next generation power systems. Grant applications must address either or both of the two types of membranes now under investigation for the recovery of hydrogen from coal gasification streams: membranes that are selective for hydrogen and membranes that are selective for carbon dioxide. Proposed membranes should achieve the following targets: (1) a high flux rate; (2) low cost; (3) improved durability; (4) low parasitic power requirements; and (5) low membrane fabrication costs.

With respect to storing the fuel, there are several advantages to using hydrogen over carbon fuels for transportation applications. First, the chemical energy per unit mass of hydrogen is higher than that for liquid hydrocarbons. Secondly, the combustion of hydrogen with oxygen, or the electrochemical reaction of hydrogen with oxygen in a fuel cell, eliminates carbon emissions. Therefore, grant applications are sought to develop materials that provide high hydrogen storage density and stability at commercially relevant conditions of temperature and pressure. The materials currently being investigated for hydrogen storage include metal



## FY 2006 Topics

organic frameworks, alloys and intermetallics, sodium and lithium alanates, nanocubes, carbon nanotubes, and other emerging materials. Proposed materials must: (1) have the potential for achieving DOE's long-term hydrogen storage goal of 3 kWh/kg (9 wt %) at a cost of \$2/kWh; (2) be amenable to realistic processing conditions and to the likelihood of large-scale manufacturing; and (3) function in the temperature range 0-100°C and the pressure range 1-10 bar.

Questions – Contact Patricia Rawls ([patricia.rawls@netl.doe.gov](mailto:patricia.rawls@netl.doe.gov))

**d. Surface Modification of Alloys for Ultrasupercritical Coal-Fired Boilers**—The implementation of ultrasupercritical boilers will require materials with high-temperature creep properties and high-temperature oxidation and corrosion resistance. New ferritic, austenitic, and nickel-base alloys have been designed to meet the creep resistance demands, but the high operating temperature poses the risk of accelerated material degradation in various harsh environments. In a coal-fired boiler, there are oxidizing and corroding environments that range from simple gas attack to the deposition microclimates of complex nature. The gases can be oxidizing, such as mixtures of O<sub>2</sub> and SO<sub>2</sub>/SO<sub>3</sub>, or a more complex mixture including aggressive gaseous compounds such as H<sub>2</sub>S, HCl, COS, CS<sub>2</sub>, CO, and methyl mercaptan. These later gaseous compounds are usually generated during the substoichiometric combustion of coals when modified combustion systems are implemented for NO<sub>x</sub> emissions control. Similarly, the substoichiometric combustion process generates unburned carbon and pyritic particulate that, based on the hydrodynamics of the fireball, may end up deposited on heat transfer surfaces. The deposits can generate various local reducing environments, ranging from carbonaceous to sulfidizing, and even low-melting eutectics that act as a flux on the metal surface.

Surface modification techniques could provide an alternative to otherwise costly nickel-base materials. The science of thermal spray has evolved in the last 15 years with the implementation of techniques, such as High Velocity OxyFuel (HVOF), that have improved the quality of the applied coatings. Other emerging techniques include cold spray technology, which when combined with nano-size powders can provide flexibility and economic advantages, and weld overlay and chromizing technologies, which are used to ensure that pressure parts are adequately protected from the operating environment. Grant applications are sought to develop new surface modification techniques, or to optimize the techniques mentioned above, for the protection of high temperature alloys used in ultrasupercritical coal-fired boilers.

Questions – Contact Udaya Rao ([rao@netl.doe.gov](mailto:rao@netl.doe.gov))

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## FY 2006 Topics

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## 17. OIL AND NATURAL GAS TECHNOLOGIES

The DOE seeks innovative methods and concepts that will contribute to more efficient and economic processes for the recovery, delivery, and utilization of oil and natural gas. Much of the known reserves of oil and natural gas in the U.S. cannot be recovered by conventional means, and advanced technologies will be required for extraction. For natural gas, utilization can be further enhanced by new technology for storage and delivery. This topic supports innovative research that supplements and complements, but does not duplicate or displace, private and other public research and development efforts. Research projects selected should contribute to the technology base by increasing production efficiency, improving predictive models and reservoir management planning, and by developing techniques for discovering oil and natural gas in complex trapping systems. Grant applications must propose a concept development effort and a work plan which should be supplemented with the development of a project team (including partnership arrangements) to pursue the idea into a workable system. A practical field test for the verification and validation of results of the work should be conducted by the end of Phase II. **Grant applications are sought only in the following subtopics:**

**a. Oil and Gas Drilling**—To prolong the sustainability of the natural gas supply over the longer-term, dramatic increases in production from deep (>20,000 ft.) reservoirs will be required. Toward this end, Deep Trek, a program addressing technical issues associated with deep drilling, is working to provide fundamental advances in high-temperature, high-pressure materials and electronics that will enable the construction of durable deep drilling and completion tools. Grant applications are sought to develop: (1) advanced technologies for well control and hole stability; with little or no damage to target formation or pass through formations; (2) new concept-changing, non-damaging drilling fluids (smart fluids); (3) novel cements that can economically replace Portland; (4) advanced unconventional completion techniques, materials, and fluids for high temperature, high pressure deep tight gas formations; (5) materials and metallurgy tubulars and tools, especially suited to handle caustic (H<sub>2</sub>S, CO<sub>2</sub>, etc.) gas resources; (6) advanced motors and drilling systems; and (7) rechargeable batteries and high temperature capacitors. All technology developments must be capable of operation in high temperature (>225°C), high pressure (>20,000 psi) environments.

Questions – Contact Jamie Brown ([jamie.brown@netl.doe.gov](mailto:jamie.brown@netl.doe.gov))

**b. Small Bore “Microhole” Drilling**—Under the Microhole Technology Initiative, the DOE will pursue a major research program in the area of drilling for oil using smaller diameter wells less than two inches. The cost to drill these wells will be significantly less than conventional oil well drilling, and the waste associated with such wells also will be much less. A recent report, "[Microhole Initiative, Workshop Summary](#)," highlights four primary applications for microhole drilling: oil development wells, reservoir data monitoring holes, shallow re-entry wells, and deep exploration tails. Additional information can be found in the [Workshop Summary report](#). Grant applications are sought to develop a helicopter transportable sonic drill system for low cost deployment of seismic instruments, such as geophones and accelerometers, to a depth of 1,500' in boreholes no larger than 2-3/4". Current sonic rigs are limited to a drilling depth of approximately 500'. The proposed system should not require use of significant volumes of drilling fluid (mud or air). The ultimate purpose of these efforts is to provide reliable, small footprint, instrumentation deployment systems that can operate at lower costs and in environmentally sensitive areas not previously accessible to conventional drilling systems.

Questions – Contact Dan Gurney ([dan.gurney@netl.doe.gov](mailto:dan.gurney@netl.doe.gov))

## FY 2006 Topics

**c. Methane Hydrates**—The objective of this funding opportunity is to receive applications for research projects that will develop new methane hydrate production tools and technologies, and/or provide a better understanding of the role of methane hydrates in the natural environment with regards to seafloor stability and safety concerns. Specifically, grant applications are sought to support 1) alternative approaches, or focused studies of new, novel, and cost-effective approaches to producing methane hydrates from natural accumulations, or 2) research that improves understanding of gas hydrates with regards to sediment/slope stability and safety issues in marine and/or permafrost settings. Applicants can review information about the DOE's National Methane Hydrate R&D Program and current DOE methane hydrate projects at, [www.netl.doe.gov/scngo/NaturalGas/hydrates/](http://www.netl.doe.gov/scngo/NaturalGas/hydrates/).

Questions – Contact Kelly Rose ([Kelly.rose@netl.doe.gov](mailto:Kelly.rose@netl.doe.gov))

**d. Advanced Diagnostics and Modeling**—Uncertainty concerning the physical and chemical nature of oil reservoirs is one of the most severe technological barriers to increasing the economic recovery. Even among like reservoirs within a single geologic region, variables often change due to temporal and spatial dynamics that occur throughout the exploitation and recovery processes. In the area of reservoir management, there is a need to characterize reservoir rock and associated heterogeneities at various scales, using a combination of various measuring technologies, and to quantify how characteristics at the different scales impact fluid movement in oil reservoirs. Therefore, grant applications are sought to develop technology for the acquisition, processing, and integration of data from multiple platforms for vertical seismic profiling (VSP). The purpose of this effort is to quantify the interrelationships between the reservoir rock architecture and the fluid-rock, fluid-gas, and fluid-fluid interactions that impact production from petroleum reservoirs.

Equally important is the interpretation of these data to guide the discovery of new oil reserves and to provide oil field development and management for maximum economic oil recovery. Therefore, grant applications are also sought for techniques to reconcile and synthesize dynamic data sets into high-resolution models. Modeling high resolution quantitative descriptions of petroleum reservoirs requires the integration of wide variety of static and dynamic data sets. In order to predict flow performance, reservoir models need be conditioned to dynamic data which may require the solution of inverse problems.

Grant applications in response to this subtopic should: (1) target geologic formations and associated oil reservoirs within U.S. basins; (2) quantify the benefits over current technology; (3) provide for future upgrading so that potential new technologies can be added; (4) consider possibilities for multidisciplinary teaming and active involvement by producers and universities; and (5) demonstrate how the results of the R&D effort will be aggressively transferred into ongoing oil industry practices.

Questions – Contact Dan Gurney ([dan.gurney@netl.doe.gov](mailto:dan.gurney@netl.doe.gov))

## References:

### Subtopic a: Oil and Gas Drilling

1. *Deep Trek Workshop Proceedings, Pittsburgh, PA, March 20-21, 2001*, U.S. Department of Energy, National Energy Technology Laboratory, 2001. (To order CD-ROM, see: <http://www.netl.doe.gov/publications/descriptions.html>)
2. Terry, D. B., et al., *Resonant Sonic Drilling at Three Former MGP Sites: Benefits and Limitations*. (Full text available at: <http://www.geiconsultants.com/images/library/sub42.pdf>)

### FY 2006 Topics

3. *A Steerable Distance Enhanced Penetrometer Delivery System*, Federal Energy Technology Center, October 1997. (Full text available at: <http://www.earthvision.net/industryprograms/pdfs/sc/31178.pdf>)
4. Amini, A. and Boyd, G. M., *Steerable/Distance Enhanced Penetrometer Delivery System*. (Full text available at: <http://www.osti.gov/bridge/servlets/purl/491963-DjFs2F/webviewable/491963.pdf>)
5. Yoseph Bar-Cohen, et al., “Ultrasonic/Sonic Drilling/Coring (USDC) for Planetary Applications,” *Proceedings of SPIE's 8th Annual International Symposium on Smart Structures and Materials*, Newport, CA., March 5-8, 2001, International Society for Optical Engineering (SPIE), 2001. (<http://ndea.jpl.nasa.gov/ndea-pub/SPIE-2001/Paper-SPIE-4327-55-USDC.pdf>)

#### Subtopic b: Small Bore “Microhole” Drilling

6. Albright, J., *Roadmap for a 5,000-Ft. Microborehole*, U. S. DOE Office of Fossil Energy. (Full text available at: <http://www.fossil.energy.gov/programs/oilgas/microhole/microholeroadmap.pdf>)
7. *Microdrill Initiative: Initial Market Evaluation*, prepared by Spears and Associates, Inc. for U.S. DOE, April 2003. (Full text available at: <http://www.fossil.energy.gov/programs/oilgas/microhole/microholemarketeval.pdf>)
8. *Microhole Initiative: [April 2003] Workshop Summary*, prepared by Spears and Associates, Inc. for U.S. DOE, June 2003. (Full text available at: <http://www.fossil.energy.gov/programs/oilgas/microhole/microhole-workshop-report.pdf>)
9. *Microhole Systems R&D*, U.S. DOE Office of Fossil Energy, <http://www.fe.doe.gov/programs/oilgas/microhole/>
10. Coiled Tubing and DOE/NETL’s Technology Development Program, U.S. DOE Office of Fossil Energy, January 2004. (Slide presentation available at: <http://www.icota.com/publications/Lunch%20Learn/NETL-ICOTA%20Luncheon%201-15-04%20Final.pdf>)

#### Subtopic c: Methane Hydrates

11. U.S. DOE *National Methane Hydrate R&D Program* and current DOE methane hydrate projects, U.S. DOE National Energy Technology Laboratory (NETL). (Available at: [www.netl.doe.gov/scngo/NaturalGas/hydrates/](http://www.netl.doe.gov/scngo/NaturalGas/hydrates/). See menu at left to view projects.)

#### Subtopic d: Advanced Diagnostic and Modeling

12. *Exploration & Production Advanced Diagnostics & Imaging*, U.S. DOE NETL. (Available at: <http://www.netl.doe.gov/scngo/NaturalGas/E&P/Adv%20Diagnostics/>)
13. *Diagnostics, Imaging & Fundamental R&D*, U.S. DOE Office of Fossil Energy. (Available at: <http://www.fe.doe.gov/programs/oilgas/fundamental/>)
14. “New Oil and Gas Projects to Enhance Energy Security, Reduce Greenhouse Gas Emissions,” *U.S. Newswire*, December 8, 2004. (Available at: <http://releases.usnewswire.com/GetRelease.asp?id=40464>)



**FY 2006 Topics**  
**PROGRAM AREA OVERVIEW**  
**BASIC ENERGY SCIENCES**

The Basic Energy Sciences (BES) program supports fundamental research in the natural sciences leading to new and improved energy technologies. The program's purpose is to create new scientific knowledge by supporting basic, peer-reviewed research in areas of materials sciences, chemical sciences, geosciences, plant and microbial biosciences, and engineering sciences that are relevant to energy resources, production, conversion, and efficiency. The results of BES-supported research are routinely published in the open literature.

A key function of the program is to plan, construct, and operate premier national user facilities to serve researchers at universities, national laboratories, and industrial laboratories, thus enabling the acquisition of new knowledge that cannot be obtained in any other way. The scientific facilities include synchrotron radiation light sources, high-flux neutron sources, electron-beam microcharacterization centers, nanoscale science research centers, and specialized facilities such as the Combustion Research Facility. These national resources are available free of charge to all researchers based on the quality and importance of proposed nonproprietary experiments.

A major objective of the BES program is to promote the transfer of the results of our basic research to advance and create technologies important to Department of Energy (DOE) missions in areas of energy efficiency, renewable energy resources, improved use of fossil fuels, mitigation of the adverse impacts of energy production and use, and future nuclear energy sources. The following set of technical topics represents one important mechanism by which the BES program augments its system of university and laboratory research programs and integrates basic science, applied research, and development activities within the DOE.

For additional information regarding the Office of Basic Energy Sciences priorities, [click here](#).

## **18. ADVANCED FOSSIL FUELS RESEARCH**

For the foreseeable future, the energy needed to sustain economic growth will continue to come largely from fossil fuels. In supplying this energy need, however, the Nation must address growing global and regional environmental concerns, supply issues, and energy prices. Maintaining low-cost energy in the face of growing demand, diminishing supply, and increasing environmental pressure requires new technologies and diversified energy supplies. These technologies must allow the Nation to use all of its indigenous resources more wisely, cleanly, and efficiently. These resources include inherently clean natural gas and the Nation's most abundant and lowest cost resource, coal. **Grant applications are sought only in the following subtopics:**

**a. Hydrogen Production from Fossil Fuels**—Clean forms of energy are needed to support sustainable global economic growth, while mitigating greenhouse gas emissions and impacts on air quality. Hydrogen systems can provide viable, sustainable options for meeting the world's energy requirements. In the long-term, research is needed to lower the cost of producing hydrogen from fossil fuels. Grant applications are sought to develop technology for the economical conversion of fossil fuels, or fossil fuel derived intermediates, into hydrogen. Of particular interest are technologies that also enable sequestration of carbon dioxide. Grant applications must show clear economic advantages over the existing state of the art.

Questions – Contact Doug Archer ([douglas.archer@hq.doe.gov](mailto:douglas.archer@hq.doe.gov))

**b. Potential for Sequestration of Greenhouse Gas Emissions and Enhanced Methane Recovery in Coalbeds**—Previous and on-going DOE-sponsored projects have focused on injecting carbon dioxide and

## FY 2006 Topics

nitrogen into coalbeds for the purpose of storing CO<sub>2</sub> and enhancing coalbed methane production. For multi-component flue gases – from fossil fuel power plants and other significant sources of greenhouse gas (GHG) emissions, including landfill gas (LFG) – there is an economic incentive to inject a greater fraction of the GHG-containing emissions into unmineable coalbeds. Such a process not only would reduce the need for the costly separation of CO<sub>2</sub>, nitrogen, and other gases but also would create the possibility of removing and sequestering other oxides (nitrogen and sulfur) from the flue gas by adsorption into the coal. Therefore, grant applications are sought to develop practical methods to: (1) accelerate the state-of-the-art for injecting greater volumes of flue gas or LFG into unmineable coalbeds; and (2) develop advanced schemes for efficiently and economically capturing, separating, and injecting maximum volumes of GHG-containing emissions from power plants, industrial furnaces, and landfills. In addition, grant applications should address the effects of corrosion and other possible adverse consequences of injecting greater fractions of the total flue gas or LFG; evaluate smaller potential coalbed methane resources for local or regional use; and identify at least one candidate scheme/approach for viable commercial-scale testing by industry.

Questions – Contact Frank Ferrell ([frank.ferrell@hq.doe.gov](mailto:frank.ferrell@hq.doe.gov))

**c. Proton Conducting Solid Oxide Fuel Cell Development**—Solid oxide fuel cells (SOFCs) typically employ oxygen-ion-conducting membranes as an electrolyte in the cell circuit. Oxygen passes through the membrane and combines with hydrogen to form a water reaction product on the hydrogen side of the cell. Alternatively, proton-conducting solid oxide membranes (analogous to the low temperature polymer membranes in PEM fuel cells) could be used, with proton-conducting solid oxide fuel cells and stacks constructed to generate power. One advantage of a proton conducting SOFC (P-SOFCs) is that the hydrogen fuel would not become diluted by the steam reaction product. Also, a proton conducting cell operating in an electrolyzer mode could produce hydrogen fuel without requiring a separation cycle to remove steam from the hydrogen product stream.

Grant applications are sought to develop P-SOFC systems, with particular attention to materials issues. In Phase I, functioning material combinations should be demonstrated at the cell level. Phase II should explore the viability of connecting multiple P-SOFC cells, culminating in the demonstration of a small stack. Grant applications also should address the technical and economic advantages and barriers for P-SOFCs compared to the more mature O-SOFC (oxygen-ion-conducting SOFC) technology and devices.

Questions – Contact Lane Wilson ([lane.wilson@netl.doe.gov](mailto:lane.wilson@netl.doe.gov))

**d. Coal Preparation**—Coal preparation technology is widely used to improve the quality of run-of-mine coals prior to delivery to the end user. However, further advances in coal preparation technologies are needed to remove the significantly larger amounts of ash-forming mineral matter, pyritic sulfur, and hazardous air pollutant precursors such as mercury. In order for the process to remain profitable while complying with environmental regulations, the coal industry not only must improve fine coal recovery but also must find better ways for its utilization. Grant applications are sought for improved coal preparation, recovery, and utilization technologies that can improve yields, at a given level of coal quality, without increasing operating costs.

Questions – Contact Doug Archer ([douglas.archer@hq.doe.gov](mailto:douglas.archer@hq.doe.gov))

## References:

### Subtopic a: Hydrogen Production from Fossil Fuels

1. *Office of Fossil Energy – Hydrogen Program Plan*, U.S. Department of Energy, June 2003. (Full-text available at: <http://www.fe.doe.gov/programs/fuels/hydrogen/programplans/2003/fehydrogenplan2003.pdf>)

## FY 2006 Topics

2. *Basic Research Needs for the Hydrogen Economy: Report on Basic Energy Sciences Workshop on Hydrogen Production, Storage, and Use, May 13-15, 2003*, U.S. DOE, 2003. (Full text available at: <http://www.sc.doe.gov/bes/hydrogen.pdf>)
3. Elam, C. C., et al., "Realizing the Hydrogen Future: The International Energy Agency's Efforts to Advance Hydrogen Energy Technologies," *International Journal of Hydrogen Energy*, 28(6):601-607, June 2003. (Abstract and ordering information available at: [www.sciencedirect.com/web-editions/journal/03603199](http://www.sciencedirect.com/web-editions/journal/03603199))
4. "Alternate Sources of Hydrogen," *Session 17, 19th North American Meeting of the North American Catalysis Society, Philadelphia, PA, May 22-27, 2005*. (Abstracts available at: <http://www.19nam.org/program.asp?SessionID=17&TypeID=D>)
5. Schobert, H., *Production of Hydrogen through Coal*, Penn State University Hydrogen Energy Center. (Summary of article available at [www.engr.psu.edu/h2e/Pub/Schobert/Schobert1.htm](http://www.engr.psu.edu/h2e/Pub/Schobert/Schobert1.htm)) (Author may be contacted at: [schobert@ems.psu.edu](mailto:schobert@ems.psu.edu)).

### Subtopic b: Potential for Sequestration of Greenhouse Gas Emissions and Enhanced Methane Recovery in Coalbeds

6. Blencoe, J. G. et al., *Effects of Temperature and Gas Mixing on Formation Pressure, CO<sub>2</sub> Sequestration and Methane Production in Underground Coalbeds*. (DOE/FE/NETL Contract Number DE-AC05-00OR2275) (Full text available at: <http://www.ornl.gov/sci/fossil/Publications/ANNUAL-2003/feaa062.pdf>)
7. Pekot, L. J., "Matrix Shrinkage and Permeability Reduction with Carbon Dioxide Injection," *Coal-Seq II Forum, Washington, DC, March 2003*. (Full text available at: <http://www.coal-seq.com/Proceedings2003/Pekot.pdf>)
8. *2005 International Coalbed Methane Symposium, Tuscaloosa, AL, May 2005*. (Abstracts of presentations available at: <http://www.bama.ua.edu/~pmdp/CoalbedAbstracts.pdf>. Please note abstracts 0509, 0510, 0518, and 0523.)
9. *Carbon Sequestration Technology Roadmap and Program Plan-2004*, U.S. DOE Office of Fossil Energy/National Energy Technology Laboratory, April 2004. (Full text available at: <http://www.netl.doe.gov/coal/Carbon%20Sequestration/pubs/SequestrationRoadmap4-29-04.pdf>)

### Subtopic c: Proton Conducting Solid Oxide Fuel Cell Development

10. Minh, N. Q. and Takahashi, T., *Science and Technology of Ceramic Fuel Cells*, Amsterdam. Elsevier, 1995. (ISBN: 0-444-89568-X)
11. *Solid State Energy Conversion Alliance*, <http://www.seca.doe.gov/>
12. "Solid Oxide Fuel Cell Developments and Applications," *Materials World*, 10(1):12-14, January 2002. (ISSN: 0967-8638)
13. Bouwmeester, H. J. and Gellings, P. J., *CRC Handbook of Solid State Electrochemistry*, Boca Raton: CRC Press, 1997. (ISBN: 0849389569)

## FY 2006 Topics

### Subtopic d: Coal Preparation

14. *Annual International Coal Preparation Exhibition and Conference: Coal Prep 2004, Lexington, KY, May 4-6, 2004*. (Available from: Primedia Business Exhibitions, 11 River Bend Drive South, Box 4313, Stamford, CT 06907-0232)
15. Sakkestad, B., ed., *Proceedings of the 29<sup>th</sup> International Conference on Coal Utilization and Fuel Systems, Clearwater, FL, April 18-22, 2004*. (Available from the Coal Technology Association, Gaithersburg, MD)
16. Leonard, J. W., ed., *Coal Preparation*, 5th ed., Littleton, CO, 1991. (ISBN: 0873351045)
17. Oder, R. R., "The Co-Benefits of Pre-Combustion Separation of Mercury at Coal-Fired Power Plants," Paper No. 990, presented at the *Air & Waste Management 98<sup>th</sup> Annual Conference and Exhibition, Minneapolis, MN, June 21-24, 2005*. (Full text available at: [http://www.magneticseparation.com/documents/AWMA\\_2005.pdf](http://www.magneticseparation.com/documents/AWMA_2005.pdf))

## 19. TECHNOLOGIES RELATED TO ENERGY STORAGE FOR ELECTRIC AND HYBRID VEHICLES

The commercial use of electric and hybrid electric vehicle technologies, including fuel cell vehicles, has been limited by a variety of technical barriers. In conjunction with the Office of Basic Energy Sciences, the Office of Energy Efficiency and Renewable Energy is interested in identifying and developing innovative concepts for advanced technologies for energy storage devices (batteries and electrochemical capacitors) that will improve the performance, extend the life, and significantly reduce the cost of the vehicles.

Battery-powered electric vehicles (EVs) require energy storage devices with high specific energy, and hybrid electric vehicles (HEVs) require devices that can deliver high power pulses. Advanced hybrids may require devices that both store significant energy and can deliver high power pulses. All of these devices must be able to accept high power recharging pulses from regenerative braking. For high specific energy systems, the near term goals are to develop cells that provide at least 150 Watt-hours/kg (Wh/kg), 230 Wh/l, 300 W/kg, and 460 W/l (with long term goals that exceed these targets); have a life of 1000 cycles at 80 percent depth of discharge; and have a calendar life of at least 10 years. For high power applications, the goal is to develop cells that provide peak power of 1000 W/kg or greater, have a cycle life of at least 300,000 shallow cycles, and have a calendar life of 15 years. For all systems, materials to be utilized should be plentiful, have low cost (< \$10/kg), be environmentally benign, and be easily recycled. Evaluation of the technology with regard to the above criteria should be performed in accordance with applicable U.S. Advanced Battery Consortium test procedures or Society of Automotive Engineers recommended practices (see references that follow).

Grant applications must show how proposed innovations would result in significant advances in performance and cost reduction over state-of-the-art technologies. Grant applications are sought only in the following subtopics:

**a. Technology to Improve the Performance of Lithium-Ion Batteries at Low Temperatures**—When lithium-ion batteries are discharged or charged at low temperatures (between -10 and -20 degrees Celsius), they exhibit poor performance relative to their performance at room temperature. For example, power capability is significantly reduced on discharge, and lithium plating on the negative electrode can occur upon charge. In fact, the loss of power below -10° Celsius is much more severe than the loss predicted from the conductivity vs. temperature relationships for conventional lithium-ion electrolyte systems. Studies of cells being cycled at low

## FY 2006 Topics

temperatures indicates that the discrepancy arises from an increase in impedance that is interfacial in nature, and fairly evenly distributed between the positive and negative electrodes.

Grant applications are sought to develop technology to address these concerns. Approaches of interest include not only improvements in cell chemistry but also technologies that operate at the battery level (i.e. at the level of multi-cell systems). Approaches that result in significantly reduced performance relative to the state-of-the-art (including room temperature performance, cycle life, calendar life, or cost) are not of interest. Grant applications must provide a clear discussion, based upon available data and theory, to support the assertion that the research will result in improved performance. Cell technologies being developed must be demonstrated in full electrochemical cells of at least 0.2 Ampere hour in size by the end of Phase I and in cells of at least 1.0 Ampere hour by the end of Phase II. Proposed technologies that will operate at the battery level must be demonstrated in modules of at least 10 cells by the end of Phase I and in modules suitable for vehicular use by the end of Phase II.

Questions – Contact James Barnes ([james.barnes@ee.doe.gov](mailto:james.barnes@ee.doe.gov))

**b. Technologies that Result in Cells with Increased Energy Density**—Recent studies indicate that currently available lithium-ion systems can not meet the energy and power goals described in this topic's introduction for high specific energy systems. Grant applications are sought to develop novel electrochemical systems that can meet these goals without compromising other performance requirements such as cost, cycle life, calendar life, or abuse tolerance. Grant applications must be for novel research and development, provide a theoretical basis for the research, address the probable cost of using the technology in vehicular batteries, and address the impact of the technology on all performance parameters. In Phase I, the technology must be demonstrated in cells of at least 0.2 Ampere-hour and accompanied by calculations designed to support the assertion that full-size cells could meet all of the performance requirements. In Phase II, performance must be demonstrated in cells larger than 5 Ampere-hours and supported by calculations designed to support the assertion that a full battery could meet all of the performance goals.

Questions – Contact James Barnes ([james.barnes@ee.doe.gov](mailto:james.barnes@ee.doe.gov))

**c. Technologies to Improve the Tolerance of Lithium-Ion Cells and Batteries to Thermal Runaway Provoked by Abusive Overcharge**—High energy and high power lithium-ion cells and batteries may be subject to inadvertent, abusive overcharge if the battery's control mechanism fails. Depending upon the failure mode, cells may experience charging voltages that exceed the design specification by as little as 100 millivolts or by many volts. Even low levels of overcharge have been shown to make a cell more susceptible to thermal runaway. More extreme overcharge can produce rapid events such as venting with smoke and flames. Recent work at universities and the national laboratories has indicated that this problem might be addressed by incorporating electroactive materials into a cell. These materials are designed to have no effect on cell operation at normal voltages; yet, they would provide a current path at elevated voltages.

Grant applications are sought to further investigate and demonstrate the electroactive-materials approach to abuse tolerance. Collaborations with research institutions already working in this area are encouraged. Grant applications must be for novel research and development, provide a theoretical basis for the research, address the probable cost of using the technology in vehicular batteries, and address the impact of the technology on other performance parameters such as calendar life, power capability, and energy density – technologies that adversely affect these parameters are not likely to be adopted. Improvements must be demonstrated in cells of at least 0.2 Ampere-hour in size in Phase I and in cells of at least 1.0 Ampere hour in Phase II.

Questions – Contact James Barnes ([james.barnes@ee.doe.gov](mailto:james.barnes@ee.doe.gov))



## FY 2006 Topics

**d. Improved Electrode Materials for Electrochemical Capacitors**—The most common electrochemical capacitors, also known as “super” or “ultra” capacitors, use a form of carbon as the active material in both electrodes. The high cost of these materials is one of the limiting factors in the development and potential adoption of capacitors for vehicular applications. Therefore, grant applications are sought that will address the cost of electrode materials in either symmetric (both electrodes are of the same material) or asymmetric (electrodes with different materials) capacitors. Replacement materials that result in reduced performance relative to the state-of-the-art (in areas such as power capability, energy stored, operating temperature, useful life, or cost) are not of interest. All proposals must provide a clear discussion, based upon available data and theory, to support an assertion that the materials to be developed will be improvements. Grant applications must include a demonstration of the materials’ performance in laboratory cells by the end of Phase I and in capacitors suitable for use in a vehicle by the end of Phase II.

Questions – Contact James Barnes ([james.barnes@ee.doe.gov](mailto:james.barnes@ee.doe.gov))

### References:

1. Links to the following Manuals are available at: [http://avt.inl.gov/energy\\_storage\\_lib.shtml](http://avt.inl.gov/energy_storage_lib.shtml). These documents provide a good general basis for understanding the performance requirements for electric and hybrid electric vehicle energy storage devices.
  - FreedomCAR 42V Battery Test Manual
  - FreedomCAR Battery Test Manual for Power Assist Hybrid Electric Vehicles
  - PNGV Battery Test Manual, Revision 3
  - Electric Vehicle Capacitor Test Procedures
  - USABC Electric Vehicle Battery Test Procedure Manual, Revision 2
2. The internet site for the Batteries for Advanced Transportation Technologies (BATT) program at <http://berc.lbl.gov/BATT/BATT.html> includes quarterly and annual reports. This program addresses many long-term issues related to lithium batteries, including new materials and basic issues related to abuse tolerance.
3. This site contains multiple references that summarize work supported by the FreedomCAR and Vehicle Technologies Program related to energy storage. Prior to 2002, there are separate publications for the Energy Storage Effort and for Advanced Technology Development. In more recent years, there is a combined report for Energy Storage. These reports include information about cell chemistries that have proven to be useful model systems for these applications along with discussions of issues related to abuse tolerance and cell life. [http://www.eere.energy.gov/vehiclesandfuels/resources/fcvt\\_reports.shtml](http://www.eere.energy.gov/vehiclesandfuels/resources/fcvt_reports.shtml).
4. Information about requirements for vehicular batteries, separators for lithium-ion batteries, and abuse testing can all be found at the USABC section of the USCAR internet site. Go to <http://www.uscar.org/>; click on “Teams”; under the USCAR Consortia section, click on “United States Advanced Battery Consortium (USABC)”. This site provides a second source for many of the documents found at reference 1.
5. The abuse test procedures, developed for FreedomCAR by Sandia National Laboratories may be accessed directly at: <http://www.uscar.org/consortia&teams/USABC/SAND99-0497%20USABC%20Safety%20Manual.pdf>

## 20. MANUFACTURING FOR THE HYDROGEN ECONOMY

America's future well-being is linked to the availability of clean, secure, and sustainable energy. To reduce or eliminate our dependence on imported oil, and to ensure that the Nation has access to domestic, clean energy supplies, the U.S. is actively engaged in research and development (R&D) of materials and enabling technologies for producing and using hydrogen as an energy carrier. This work is being done through the President's Hydrogen Fuel Initiative, announced in January 2003.

As hydrogen products become broadly introduced into the marketplace, their cost and thus their pricing will be heavily influenced by their manufacturability. Research and development on manufacturing for the hydrogen economy is needed to ensure that hydrogen products can be made in an economically viable manner in large quantities, and that they will conform to design specifications, performance functionality, codes and standards, safety requirements, and customer requirements. This topic addresses the manufacturing processes needed to support the production scale-up of hydrogen and hydrogen products, at both component and systems levels.

**Grant applications are sought only in the following subtopics:**

**a. Manufacturing of Hydrogen Production Equipment**—Today, the cost of high-volume hydrogen production and delivery is two to three times the DOE targeted untaxed price of \$2.00-3.00/gge (gasoline gallon equivalent on an energy basis). One of the barriers to cost reduction is the lack of manufacturing capacity for producing the significant quantities of small-scale systems that will be needed for the distributed production of hydrogen - systems that must produce up to 1,500 kilograms of hydrogen per day. These systems, which could be required in large quantities to support a growing hydrogen economy, will be needed for the reforming of natural gas or renewable liquids and for electrolysis of water. Grant applications are sought for the research and development of high volume manufacturing of systems and components for distributed reforming and electrolysis. Particular needs include the low-cost manufacture of: (1) compact, integrated reforming systems that can operate in an unattended manner, (2) electrolyzer stacks and balance-of-plant components. Specific research thrusts could address processes and equipment for: (1) coating catalysts on non-conformal surfaces, (2) joining dissimilar materials to integrate components into subsystems, (3) joining materials at low temperatures to avoid damage to components, (4) rapidly assembling electrolyzer stacks, (5) on-line manufacturing process control, (6) manufacturing gas clean-up subsystems, and (7) manufacturing seamless pressure vessels.

Questions – Contact JoAnn Milliken ([joann.milliken@ee.doe.gov](mailto:joann.milliken@ee.doe.gov))

**b. Manufacturing of Hydrogen Storage Containers**—In the near term, hydrogen will be stored on board vehicles as a compressed gas at ambient and cryogenic temperatures, and as a liquid. Robust, lightweight, high-strength storage tanks are needed for compressed, cryogenic, or liquid storage of hydrogen. The development of improved high-volume manufacturing processes will play a role in reducing the current cost of onboard hydrogen storage systems to meet the DOE target of \$2/kWh (approximately \$300 for 5-kg hydrogen storage system).

Limited supplies of tanks for storing compressed hydrogen gas at 5,000 pounds per square inch are now being manufactured in pilot production plants. These storage vessels are typically carbon-fiber based, and their manufacture requires precise winding of the fibers over a mandrel to ensure a controlled alignment and spacing of the fibers. This process is very costly. Further costs are incurred by time-consuming processes for infiltrating and curing the epoxy filler, processes that are critical for eliminating flaws in the pressure vessel and ensuring safety during use. Although recent reports have suggested that low-cost fibers and an optimal winding technology may bring down the cost, fiber winding and processing remain very labor-intensive.

Liquid hydrogen storage systems also are being produced in small volumes for onboard applications. Construction of these systems requires the fabrication of containers that can store and maintain hydrogen at

## FY 2006 Topics

about four degrees Kelvin. For these systems, effective thermal insulation barriers are required. Also, there are applications for which compressed hydrogen gas could be stored at cryogenic temperatures.

In addition to onboard hydrogen storage requirements for automotive applications, the low-cost bulk storage of hydrogen – at refueling stations, stationary power sites, terminals, on transport trucks, and in other parts of a hydrogen delivery infrastructure – will be vital to achieving the goals of the Hydrogen Fuel Initiative. Another potential solution for the bulk storage problem is to store the hydrogen as a compressed gas at 5000-10,000 psi, provided that the cost of the storage vessels could be reduced.

To address the above problems, grant applications are sought for the research and development of manufacturing processes for both components and complete storage system for onboard and/or off-board hydrogen storage applications. Areas of interest for composite tanks include the development of new manufacturing processes that: (1) reduce the cost of carbon fiber materials (processes of interest include improved methods for carbonization/graphitization, surface treatments, and spinning, as well as alternate precursor routes and oxidation methods such as microwave-assisted techniques), (2) increase production rates and reduce costs through (a) faster winding of filaments and (b) faster and more thorough impregnation methods for the resin matrix, (3) reduce the required content of carbon fiber by rapidly embedding sensors during manufacture, and (4) can be used to produce conformable high pressure storage systems.

Areas of interest for liquid hydrogen and cryogenic gas storage systems include the development of new manufacturing processes that reduce the cost and increase the rate of manufacturing of: (1) thermal barriers through faster processing of vacuum liners, (2) compact, high efficiency thermal management assemblies for storage systems, (3) metal tanks through improved forming/extrusion processes, and (4) complete storage systems through high volume assembly of components into finished systems.

Areas of interest for chemical and solid state hydrogen storage systems include the development of new manufacturing processes that reduce the cost and increase the rate of manufacturing of: (1) volume exchange bladders and cartridges for chemical systems, (2) tanks for all types of systems, and (3) microchannel components for solid state systems.

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**c. Manufacturing of Proton Exchange Membrane (PEM) Fuel Cells**—Fuel cell stacks are typically manufactured using laboratory fabrication methods that have been scaled up in size, but do not incorporate high volume manufacturing methods. For fuel cells based on proton exchange membrane (PEM) technology, the assembly of membrane electrode structures is performed as a discrete operation, with most of the actual labor done by hand. Assembly requires the repetitive measurement of stack components, as well as close tolerances for seal connections, to assure that quality and performance are maintained. Today the projected high volume production cost of fuel cells is about seven times the DOE target of \$30/kW.

The manufacturing of ancillary equipment, such as compressors, flow controllers, and converters, also must be addressed. Some major subsystem components, such as the air delivery system and the cooling system, are individually assembled and then joined together (the air blower must be integrated with the humidification system, and the coolant system must be connected to the heat exchangers).

Lastly, the need for precious metal catalysts presents a significant contribution to the overall cost of fuel cells. Recognized, reliable, and repeatable measurement technologies during manufacture could optimize the catalyst application within the fuel cell stacks, further reducing fuel cell costs.

## FY 2006 Topics

Grant applications are sought for research and development of manufacturing processes and associated quality control processes for PEM fuel cell components and complete systems. Areas of interest include: (1) thin film manufacturing, (2) deposition of catalysts onto thin films, (3) production of carbon or metal bipolar plates, (4) integration of sealing processes with manufacture of manifolds, (5) joining of materials, (6) production of air blowers/air compressors for PEM applications, (7) manufacturing of light-weight heat exchangers, (8) equipment for the rapid assembly of PEM cell stacks, (9) agile manufacturing processes that can be adapted economically to evolving membranes, catalyst layers, and gas diffusion layers, (10) high volume process control providing required performance of MEAs, and (11) cost competitive manufacturing approaches for low to medium volume manufacturing.

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## 21. SEPARATION TECHNOLOGIES

Separation technologies recover, isolate, and purify products in virtually every industrial process. Pervasive throughout industrial operations, conventional separation processes are energy intensive and costly. Separation processes represent 40 to 70 percent of both capital and operating costs in industry. They also account for 45 percent of all the process energy used by the chemical and petroleum refining industries every year. Industrial efforts to increase cost-competitiveness, boost energy efficiency, increase productivity, and prevent pollution demand more efficient separation processes. In response to these needs, the Department of Energy is seeking the development of high-risk, innovative separation technologies in processes for distillation, adsorption, and dewatering. Also sought are innovative separation processes that are applicable to biomass slurries. Grant applications must address the potential public benefits that the proposed technology would provide from reduced energy consumption and from the reduction of materials consumption, water consumption, and/or the dispersion of toxins and pollutants. Grant applications should also include a plan for introducing the new technology into the manufacturing sector, in order to access capabilities for widespread technology dissemination. **Grant applications are sought only in the following subtopics:**

**a. Distillation**—Significant quantities of inorganic acids, and all commodity organic chemicals, are purified by distillation at some stage in their manufacture. Distillation accounts for more than 60% of the total process

## FY 2006 Topics

energy used for the manufacture of commodity chemicals and is therefore a meaningful target for improvements in energy efficiency. Grant applications are sought to develop new technologies for significantly enhancing the energy efficiency of existing distillation systems used in the U.S. for the manufacture of any major commodity chemical, both inorganic and organic. Areas of interest include: (1) systems integration in commodity chemical manufacture that could be implemented at an attractive cost and reduces currently needed distillation capacity; (2) hybridization of distillation with other more efficient means of separation such as membranes – but before developing this approach, the history of commercial attempts to introduce efficient hybrid distillation systems should be carefully reviewed; (3) design and development of new column internals, such as the reboiler and the condenser, provided that the technology can be demonstrated at an acceptable cost and payback period; and (4) processes that take advantage of the excess reactive distillation capacity that may result from regulations on oxygenated fuel additives in the chemical industry, provided that the new processes enhance energy efficiency over the processes replaced.

Grant applications should include a review of the state-of-the-art of the targeted distillation application in the U.S., including a review of its current inefficiencies, in order to provide a sound technical basis for the efficiency gains to be expected from the technology development effort. Strategies to overcome the inefficiencies should be identified and practical means to address them developed. The number of distillation units in the U.S. that could apply the new technology should be identified, along with the energy savings that could be derived by reasonable market penetration. The cost of applying the new technology and the ease of implementation are also important. Approaches must demonstrate an attractive cost, maintain (or enhance) system reliability and safety, be capable of retrofit at attractive cost, and meet or exceed the performance characteristics demanded of distillation systems. Incremental improvements to existing distillation technologies are not of interest, nor is technology that is not broadly applicable to distillation as applied today in commodity chemical manufacture.

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**b. Adsorption**—Adsorption uses special solids (called adsorbents) to remove substances from gaseous or liquid mixtures. Adsorption is effective for purifications, e.g. taking a contaminant ranging from 1 ppb to 1000 ppm out of a stream of gas or liquid. In addition, adsorption is good for bulk separations, e.g. taking 1 to 50% of a component out of a stream of gas, or maybe 1 to 10% out of a liquid. Adsorption is also used for the recovery of certain constituents (e.g., solvents from air), preventing pollution, separating impurities from natural gas, petrochemical separations, hydrogen purification, recovery and reuse of sulfur dioxide for metalcasting, and so on. Advances in, and the expanded use of, adsorption have resulted in substantial energy, environmental, and economic benefits in a number of industrial settings. One prominent example is in refineries and petrochemical plants, where pressure swing adsorption (PSA) has replaced cryogenic distillation as the most economical method for separating hydrogen from various compounds; by replacing cryogenic distillation with PSA, refineries and petrochemical plants have been able to reduce costs by anywhere from 60% to 90%.

Grant applications are sought in adsorbent and adsorption process development. The new adsorbents must have high capacity, rapid adsorption-desorption kinetics, improved selectivity, and operational stability at elevated temperatures in the presence of steam and other reaction components. The new adsorption processes must then take advantage of these new materials. Grant applications must address one of the following priorities: (1) development of high capacity CO<sub>2</sub> and CO selective adsorbents that can operate in the presence of hydrogen and steam at elevated temperatures (working capacities in the range of 3-4 mol/kg are of particular interest), along with the development of new Pressure Swing Adsorption (PSA) or Temperature Swing Adsorption (TSA) cycle designs (possibly a PSA/TSA hybrid cycle design), at either ambient or elevated temperatures, that take advantage of these new adsorbents; (2) development of advanced structured adsorbent materials for use in rapid-cycle PSA, and further development of the design of rapid-cycle PSA; (3) development of novel PSA hybrid separation systems, e.g. with a structurally integrated permeable membrane; (4) CO<sub>2</sub> removal via TSA –



## FY 2006 Topics

development of TSA and/or PSA/TSA hybrid cycles with improved materials for use in H<sub>2</sub> separation technology and other applications; (5) improved hydrogen separations with Sorption Enhanced Reaction Processes (SERP), using a thermal swing regeneration and new materials – novel approaches, such as incorporating a high temperature reversible metal hydride as a H<sub>2</sub> selective adsorbent in a SERP to drive the equilibrium, should be considered; and (6) CO selective adsorbents.

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**c. Advanced Dewatering**—The separation of water from a feedstock, product, or by-product stream is a common, often energy-intensive function in many industrial manufacturing processes. For example, dewatering processes in the pulp and paper industry, including paper forming and market pulp production, consume on the order of 4 -5 MMBtu/ton of product. Thermal dewatering techniques, while more effective than mechanical techniques for some systems (e.g., where there is a high solids content), require excessive space and capital in addition to consuming large quantities of energy.

Dewatering applications are also found in a variety of other industries including food processing, agriculture, chemicals, and mining. The dewatering of citrus pulp and other food slurries is highly energy-intensive, as are many food drying processes and the dewatering of food crops and agricultural waste products. Applications in the chemicals and wastewater treatment industries include dewatering of industrial sludges and chemical intermediates, as well as the dewatering required for oil/water separations and many other solid/liquid separations. In the mining industry, dewatering helps recover valuable minerals from ores, improve materials handling, process coal slurries, and reduce the amount of fine material entering waste streams. Novel dewatering techniques could also improve the ability to recover the iron contained in steelmaking sludges.

Grant applications are sought for breakthrough dewatering technologies that can dramatically lower energy consumption, improve energy intensity, and reduce the capital cost of equipment. In addition to improving many different processes within the manufacturing sector, advanced dewatering technologies also could provide benefits to the municipal wastewater and power production markets.

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**d. Biomass Separation Process Technologies**—Process streams resulting from the primary fractionation/saccharification of lignocellulosic biomass are typically highly complex slurries that are difficult to process and separate. Such slurries often contain substantial levels (10-20% w/w) of insoluble lignocellulosic solids as well as high concentrations of soluble biomass sugars (>10-20%) along with a variety of other soluble components (organic and inorganic acids, aldehydes, phenolics, etc.) that are typically present at lower levels. Advanced separation process technologies, which would enable more cost effective solid/liquid (S/L) separations of such slurries, are needed for bulk or primary S/L separations, as well as for secondary/polishing S/L separations. Therefore, grant applications are sought to develop: (1) improved upstream fractionation, to recover products and/or facilitate bio/catalysis and to reduce the cost of downstream recovery and purification; (2) advanced concepts such as reactive separations schemes that will enable *in situ* combination with bio/catalysis steps, or approaches that are substantially more energy efficient and/or require much less capital equipment; (3) techniques to remove smaller suspended particles or high molecular weight compounds from partially clarified liquors, in advance of further purification by chromatography or concentration and/or purification by evaporation and/or crystallization; and (4) efficient membrane separation systems that enable more economic and efficient separation and recovery of specific components (e.g., specific sugars or organic acids) or classes of components (e.g., mixed sugars or mixed phenolics) from clarified biomass hydrolyzate liquors. Progress in these areas will reduce the need for bio/catalysts to tolerate impurities and interfering components, and will help reduce the cost of producing fuels and chemicals from biomass processing streams.

## FY 2006 Topics

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## 22. NANOTECHNOLOGY

The DOE is poised to apply many of the recent discoveries in nanotechnology by universities and national laboratories, which may have an important influence on the manufacture and uses of chemicals and materials. In this topic, small businesses are encouraged to take advantage of these discoveries by conducting further R&D, leading to marketable products of importance to the U.S. industrial manufacturing sector. The subtopic areas focus on solar photovoltaics, nanomaterials for chemical synthesis and separation processes, nanoelectronics, and solid state lighting. Grant applications must demonstrate a significant energy benefit, either from saving energy in manufacturing, conserving materials, or providing longer life in applications. Grant applications also must demonstrate how these nanotechnology innovations will be introduced into the marketplace, possibly in conjunction with major industrial companies that have capabilities for widespread

## FY 2006 Topics

technology implementation and manufacturing. **Grant applications are sought only in the following subtopics:**

**a. Solar Photovoltaics (PV) Technology**—Further cost reduction of PV is being pursued to accelerate its penetration into the renewable energy market. Module packaging and reliability, improved thin films, and innovative materials are being addressed to achieve these cost reductions. Grant applications are sought to develop and manufacture solar cells based on the innovative use of emerging nanoscale materials, including polymers, small molecules, dyes, chromophores, or other materials (e.g. quantum structures of inorganic materials). The goal is to develop solar cells with efficiencies greater than 10%, using designs capable of achieving good reliability, low cost, and easy manufacturability. The synergies between photovoltaics and the applications of nanotechnologies should demonstrate the opportunity for further efficiency enhancements and associated manufacturing cost reductions.

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**b. Nanomaterials for Chemical Manufacturing**—The innovative application of nanomaterials could have significant implications on a number of chemical processes, especially catalysis and separations.

Recent discoveries suggest that some materials with nanosized features may exhibit novel heterogeneous catalytic activity. Therefore, grant applications are sought to develop new nanoscale materials with catalytic properties. Chemical transformations of interest include, but are not limited to isomerizations, halogenations, oxidations, reductions, stereospecific transformations, or combinations thereof. Proposed approaches must demonstrate that (1) the materials exhibit catalytic behavior only when their functional properties are imparted at the nanoscale, and (2) the intended products of the chemical reactions have commercial value.

Other recent developments suggest that nanotechnology could greatly contribute to more-energy-efficient separations technology in areas such as molecular sieves, membranes, and sorbents. Grant applications are sought to develop new nanotechnology-based separations technology for any industrial separation process, provided that significant increases in energy efficiency can be demonstrated compared to the technology that is augmented or replaced. Applicants are strongly urged to carefully review the scientific literature and patent databases related to the proposed technology, before submitting an application. In order to assure the rapid commercialization of the new technology, applicants are encouraged to form partnerships with chemical manufacturers, suppliers to the industry, and end users.

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**c. Nanoelectronics and Nano-Electro-Mechanical Systems for Industrial Process Measurement and Control**—Microelectronics and micro-electro-mechanical (MEMS) systems have enhanced process control by allowing for process-variable measurement and response to environmental changes in situations where ordinary sensors and controls would be either impractical or impossible to apply. These microsystems are now moving to nano dimensions in such devices as quantum dots and single molecule lasers. One advantage is that, at nano dimensions, some of the high temperature limitations of MEMS devices could be overcome. Grant applications are sought to apply nanoelectronic measurement systems and devices to industrial process control. All commercial industrial processes, including combustion and product manufacture, are of interest. Grant applications must demonstrate that using the nano devices or systems will provide significant energy or materials savings through enhanced process control. Applicants are encouraged to form teams of researchers and manufacturers that will work together for the rapid commercialization of the technology. In particular, companies that specialize in industrial process controls would be a valuable addition to the development and commercialization team.

## FY 2006 Topics

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**d. Solid State Lighting in Buildings**—New products and applications, based on nanoscience and nanotechnology, could provide significant improvements in solid state lighting. This subtopic addresses two areas of primary interest: advanced phosphors and semiconductors. Grant applications must identify: (1) targeted applications and markets that will use the new materials; (2) the energy benefits to be obtained from using the new materials; (3) the basis in nanoscience for the properties of the new materials that will benefit the targeted application; and (4) a pathway to the commercialization of the new technology, which could include the identification of a manufacturer prepared to assist with commercialization.

Advanced Phosphors Using Nanotechnology: Phosphors are used in a wide range of lighting products, ranging from conventional fluorescent lighting to more contemporary solid-state devices. Modern fluorescent lighting consumes more than 40% of the total energy attributed to lighting and is especially prominent in commercial and industrial spaces, producing about 60% of the light used there. These lamps, especially T-8 linear fluorescent lamps (LFLs), produce very high quality light with acceptable energy efficiency over an extensive lifetime, and compact fluorescent lamps (CFLs) are not far behind. However, even the best of today's T-8 LFLs convert only about 28% of consumed power into visible radiation. Mostly, this inefficiency is attributed to electrode losses (~16%), unwanted infrared emissions (~37%), and other discharge column losses (~18%) including small amounts of ultraviolet emission. Solid state lighting (SSL) devices such as light emitting diodes (LEDs) also depend upon phosphors to convert some of their blue or near ultraviolet radiation into useful visible light. However, as bright and efficient as these devices have become in recent years, the conversion of monochromatic light into broad spectrum, white light is not particularly efficient, with less than 40% of the light produced within the semiconductor released to serve useful purposes.

Certain nanocrystalline structures have demonstrated the potential to increase the efficiency of converting UV to visible light, and to improve the efficiency of releasing visible photons, in conventional lighting products such as linear or compact fluorescent lamps. Also, in semiconductor devices such as LEDs and OLEDs, other types of nano-structures have demonstrated the ability to alter emissive wavelengths or enhance certain IR capture mechanisms. Grant applications are sought to extend these promising nanotechnologies to energy efficient products for general illumination. Grant applications must: (1) build upon the established science associated with various nanoscale effects including, but not limited to, photonic lattices or crystals, quantum dots, and nanocrystalline structures comprised of conventional phosphors; (2) demonstrate the practicality of the improved lighting products using the subject nanotechnology; (3) provide the potential for energy efficiency improvements of at least 20%; and (4) identify a clear pathway to manufacturing, for example, by establishing relationships with existing lamp manufacturers, in order to reduce technical risk and promote the likelihood of success.

Novel active or thermal material for semiconductors: High brightness LEDs, used in general illumination applications, are derived from III-V materials systems. While already possessing good internal quantum efficiency (IQE) at the die level, there is room for improvement in out-coupling or external quantum efficiency (EQE). Grant applications are sought to develop novel materials, derived from research in various nanoscale technologies such as quantum dots or nano-phosphorescent structures, that could be integrated into devices to increase both IQE and, even more likely, EQE. These improvements may take place within the active regions of the semiconductor structure or within the various components or layers that comprise the device.

In addition, currently envisioned SSL devices are limited by their capacity for heat rejection and current distribution. Both of these constraints may be relaxed by using nanoscale materials or structures that either increase thermal conduction while maintaining desirable optical properties or by delivering more electrons (or holes) to appropriate active areas of the semiconductor. Grant applications are sought to exploit these nanoscale effects in order to improve the performance of semiconductor lighting devices.

## FY 2006 Topics

For both the LEDs and the SSL devices, grant applications must: (1) build upon proven scientific observations; (2) apply the identified nano-technology to inorganic, organic, or even hybrid semiconductor designs; and (3) include clear projections of increased efficiency in comparison to materials systems of conventional design.

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## 23. CHEMICAL REACTIONS

About 90 percent of chemical manufacturing processes and more than 20 percent of all industrial products in the U.S. employ underlying catalytic steps. For petroleum refining, over 80 percent of its processes involve catalysis. Catalysis also plays a substantial role in the production of 30 of the top 50 U.S. commodity chemicals. Of the remaining 20, six more are made from raw materials produced catalytically. The energy use component in the production of the top 50 chemicals is significant – 5 quadrillion BTUs per year – 3 quadrillion



## FY 2006 Topics

BTUs per year for those with catalytic production routes. It has been estimated that if all the catalytic processes associated with petroleum refining and with chemical manufacture of the top 50 chemicals were raised to their maximum yields, total energy savings would exceed one quadrillion BTUs per year. More efficient chemical production, resulting from improvements to catalytic processes, would also contribute to significantly reduced carbon emissions. This topic seeks to accelerate the catalyst discovery and applications process by identifying catalysts that have higher selectivities, can operate at modest temperatures and pressures, and contribute to a reduction in the number of unit operations. It is intended that R&D be conducted to overcome current limitations of selectivity and efficiency, leading to substantial energy savings, improved economic performance, enhanced utilization of feedstocks, and reduced requirements for materials of construction.

Grant applications must address the potential public benefits that the proposed technology would provide from reduced energy consumption and from the reduction in one or more of the following: materials consumption, water consumption, and toxic and pollutants dispersion. Grant applications should also include a plan for introducing the new technology into the manufacturing sector, in order to access capabilities for widespread technology dissemination. **Grant applications are sought only in the following subtopics:**

**a. Heterogeneous Catalysis**—Catalytic reforming, catalytic cracking, hydrocracking, alkylation, isomerization, and the conversion of methanol into olefins are some of the most important industrial applications of heterogeneous catalysis. For example, the synthesis of oxygenated compounds from hydrocarbons involves heterogeneous oxidation catalysis, the cracking of paraffins to olefins, and the subsequent direct or indirect addition of oxygen. In such processes, the direct addition of oxygen to olefins is exothermic, and, therefore, increased selectivity would provide energy savings from reduced hydrocarbon feedstock requirements. Indeed, the enhancement of oxidation selectivity represents the largest potential improvement of energy efficiency in the chemical industry (Parshall, 1994). Grant applications are sought for the research and development of technologies for improving the efficiency of industrial catalytic oxidations, reductions, and acid-base catalysis. Areas of particular interest are: (1) selective oxidation of petroleum feedstocks for commodity chemicals, thereby enhancing efficiency by reducing over-oxidation; (2) alkane activation for direct oxidation with molecular oxygen, e.g., methane to methanol; (3) heat integration of catalytic oxidations with other processes; (4) improvements in the syntheses or use of reactive intermediates; (5) new catalysts for commodity chemical reductions including ammonia synthesis from elemental gases, fuel and gas reforming catalysts, and cathodic catalysts for fuel cells – new ideas for fuel cell catalysts for oxygen activation are especially desired; and (6) new and improved catalysts for petroleum cracking in a fluidized bed, as well as new heterogeneous catalysts for alkene/alkane alkylation.

Questions – Contact Charles Russomanno ([charles.russomanno@hq.doe.gov](mailto:charles.russomanno@hq.doe.gov))

**b. Homogeneous Catalysis**—Isomerizations, hydrogenations, oxidations, polymerizations, and esterifications are just a few of the many commercial applications of homogeneous catalysis. The DOE has a long and respected history of support for the development of homogeneous catalysts used for polymer syntheses, as well as homogenous catalysts used for chemical synthesis from synthesis gas. Grant applications are sought for the development of new homogeneous catalysts for these applications, especially homogeneous catalysts that avoid the use of precious metals such as rhodium. Grant applications that address the use of unenriched synthesis gas from biomass for chemical manufacture are also of interest.

Questions – Contact Charles Russomanno ([charles.russomanno@hq.doe.gov](mailto:charles.russomanno@hq.doe.gov))

**c. Conversion of Biomass-Based Platform Outputs**—Catalysis has been identified as an important, but only modestly applied, technology for the conversion of biomass-based platform outputs, i.e., sugar/lignin and oils. Catalytic processes to improve yields and selectivity would be useful in producing several defined-carbon-number building blocks and in converting these building blocks into other secondary chemical intermediates or

## FY 2006 Topics

even actual products. The conversion chemistry for biomass components, particularly when the components tend to be in aqueous systems, has not been sufficiently developed for wide spread application. Therefore, grant applications are sought for new, selective catalytic transformations of biomass-based platform outputs, leading to new or existing compounds of defined carbon number that can serve as building blocks within an integrated biorefinery. Of particular interest are: (1) selective oxidation and reduction processes, and processes that promote the selective C-C bond breaking of biomass components – sugars, lignin (aromatics from lignin), and plant oils; (2) new, selective catalytic transformation chemistry involving conversion of building blocks derived from sugars into useful intermediates; and (3) improved catalysts for biomass, and/or biomass derived-liquids, reforming and shift processes, to reduce tar formation, improve selectivity to hydrogen, and increase production rates.

Questions – Contact Charles Russomanno ([charles.russomanno@hq.doe.gov](mailto:charles.russomanno@hq.doe.gov))

**d. Bioprocessing**—Bioprocessing with enzymatic or microbial systems for the selective transformation of biomass-based platform outputs, especially sugars, continues to be a fertile field of scientific research and commercial development. In fact, the integration of bioprocessing into biorefinery operations remains an ongoing effort within the DOE Biomass Program. However, DOE analyses suggest that the cost-effective and continuous production of many building blocks, as well as the conversion of these building blocks into larger intermediate-scale and commodity-scale production in a biorefinery, is not yet viable. Therefore, grant applications are sought to develop: (1) novel and innovative approaches to adapt current batch bioprocesses into continuous processing systems, commensurate with the production of compounds of defined carbon numbers to serve as building blocks within an integrated biorefinery; or (2) entirely new approaches for the enzymatic or microbial bioprocessing of biomass-based platform outputs that can produce compounds of defined carbon number to serve as building blocks within an integrated biorefinery – of particular interest are biological conversions from mixed or impure sugar streams, which are derived from various pretreatment or existing industrial processes.

Questions – Contact Charles Russomanno ([charles.russomanno@hq.doe.gov](mailto:charles.russomanno@hq.doe.gov))

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## FY 2006 Topics

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## 24. SOLID-STATE LIGHT EMITTING DIODES FOR GENERAL ILLUMINATION

In some limited instances, solid-state lighting (SSL) products on the market today contribute to energy conservation in general illumination applications such as exit signs or task lighting. However, due to a number of performance limitations, most SSL products are used in applications that do not produce the large energy conservation results sought by the DOE for general illumination. To address these shortcomings, the DOE has engaged the rapidly expanding SSL industry and research community in several workshops<sup>(1,2,3,5)</sup> that have identified high priority research needs. The objective of this topic is to encourage small business participation in addressing these needs, in order to overcome the significant technical challenges that restrict the application of SSL to only relatively low luminous output products. Grant applications must include a complete discussion of: the innovation, the anticipated improvement in luminous efficacy, and the project’s potential impact on device cost, potential lifetime, and practical methods of current distribution and control. **Grant applications are sought only in the following subtopics:**

**a. High Efficiency Visible and Near UV (>380 nm) Semiconductor Materials for LED-Based General Illumination Technology**—Current III-nitride compound semiconductors are incapable of achieving the price and performance targets the DOE believes are necessary to be competitive in general illumination applications (see references). In particular, novel and significant advances in the basic materials technology associated with visible and near UV light emitting diodes (LEDs) will be needed to achieve white-light-producing devices with performance that exceeds 50 to 80 lumens per watt (lm/W), now available in present day devices. These advances not only must produce substantial gains in light production efficiency, but also must reduce the significant costs normally associated with the complex and labor intensive epitaxial growth required to produce these devices. Grant applications are sought to develop significant materials-systems improvements over conventional nitride systems performance, along with new approaches to LED technology, ultimately leading to devices capable of producing full spectrum, white light at 100 lm/W or greater. Areas of interest include those described in the SSL workshop proceedings such as significant advancements in P-doping efficiency; novel

## FY 2006 Topics

charge introduction structures; and novel growth techniques and approaches, including lateral epitaxy overgrowth; and reduction of defects, dislocations, and other crystalline artifacts. Grant applications must: (1) represent significant unique approaches compared to previous and on-going projects described at the most recent workshop [reference 6]; (2) show that improvements of several orders of magnitude, in the price and performance of these devices, are likely; and (3) compare performance to devices described in the most recent SSL workshop [6].

Questions – Contact James Brodrick ([james.brodrick@hq.doe.gov](mailto:james.brodrick@hq.doe.gov))

**b. High Efficiency Materials for OLED-Based General Illumination**—Present day designs for organic light emitting diodes (OLEDs), which are candidates for general illumination purposes, are usually derived from materials and architectures associated with display applications. In order to serve as viable alternatives to conventional luminous sources, including inorganic LEDs, OLEDs must meet different price and performance levels. Current OLED materials simply do not possess the color gamut, efficiency, or lifetime necessary to qualify them as viable candidates for the unique demands of the general illumination market. Estimates of lifetime and efficacies necessary for OLED-based general illumination are in excess of 50,000 hours and 100 lumens per watt (lm/W), respectively. However, state-of-the-art, white OLEDs (at 850 cd/m<sup>2</sup>) have a lifetime and efficiency of approximately only 1000 hours and 15 lm/W, respectively. To realize the full potential of OLED technology, new materials and systems, which offer the promise of vastly improved efficiency and stability, must be developed.

In laboratory experiments, monochromatic OLED systems have already achieved luminous efficiencies in excess of 100 lm/W with external quantum efficiencies greater than 20%. However, many challenging technical issues still remain, in order to achieve the targeted OLED lifetime and performance at the relatively high intensities and with the broad white emissions needed for general illumination applications. Reports from recent workshops identified a list of high priority OLED research issues areas [5, 6]. Consistent with these documents, grant applications are sought to develop new OLED materials and systems to achieve the above OLED performance requirements for general illumination. Grant applications must specifically address one of the high priority research opportunities cited in these documents including the following, which are of special interest: (1) monomer structures that produce broadly emissive white light at efficacies approaching 100 lm/W; (2) advanced light extraction theory, along with novel techniques for improving upon the low device extraction efficiency characteristic of today's devices; and (3) alternative transparent conductive oxides coatings, whose optical and electrical properties eclipse those of indium tin oxide [7].

Questions – Contact James Brodrick ([james.brodrick@hq.doe.gov](mailto:james.brodrick@hq.doe.gov))

**c. Advanced Phosphors for UV or Blue LEDs**—There are many applications for advanced phosphors in solid-state lighting (SSL) devices. Examples include relatively simple wavelength converters for LEDs that absorb high energy, monochromatic photons (e.g., near UV or blue) and emit new photons with a lower energy but with a broader spectrum of color approaching that of white light. More elegant applications include complex nanocrystalline devices that use a combination of crystal size and photonic interactions to potentially alter the emissive properties of a semiconductor, making it more suitable for general illumination.

SSL sources used for general illumination applications today are almost exclusively designed around near UV or blue emitting LEDs [4]. These sources capture a portion of the monochromatic emissions with a yellow phosphor, which, in turn, converts some of the pump light into a broader spectrum whose combined emissivity approximates white light of good color and spectral power. Although many of the materials currently used for these purposes are reasonably efficient, grant applications are sought to develop more efficient phosphors and/or luminescent materials, in order to provide the needed increase in overall device efficiency. Areas of interest include: (1) multi-photon processes, which can produce quantum yields in excess of unity, even for

## FY 2006 Topics

relatively low energy excitations such as 380 nm – for these, suitable hosts and materials systems must be developed in order to produce practical, energy efficient devices for general illumination products; (2) down-conversion approaches to white light generation, which will require the development of more efficient (>95%), stable (100,000 hrs), high-temperature (>150 degrees C), environmentally friendly phosphors with no dissipative optical absorption or scattering; (3) novel approaches for the synthesis and processing of novel conversion materials, including, but not limited to nanocrystalline semiconductors, photonic lattices, quantum dots, organic coordination-compound phosphors, phosphor blends or slurries, and coated phosphors; and (4) encapsulation materials needed for high-drive, high-lumen output LED devices for general illumination – future encapsulation materials for high-power products will need to have an index greater than 1.6, high transmission (>80%) through thick layers throughout the visible spectrum (440-650 nm), UV filtering and resistance, low H<sub>2</sub>O permeability for up to 100,000 hours, and the capability to withstand high processing and operation temperatures (100-150 C).

Questions – Contact James Brodrick ([james.brodrick@hq.doe.gov](mailto:james.brodrick@hq.doe.gov))

**d. Advanced Materials for Thermal Management in III-Nitride LEDs** – High brightness (HB) LEDs used in general illumination applications today and in the very near future are derived from III-V materials systems [6]. While already possessing good internal quantum efficiency at the die level, at the chip level they are limited in luminous output by their ability to manage heat and light efficiently and simultaneously. Grant applications are sought to develop advanced materials systems that can increase the thermal conduction of heat – produced in the die and conducted through the chip to the device and, ultimately, to the environment) – in order to permit more aggressive chip configurations and luminous power. In turn, even higher output HB LEDs could be manufactured from conventional materials and growth methods. Examples of such advanced materials technology include metal oxides or conductive structures impregnated into conventional chip substrates. By demonstrating an improved thermal management pathway at the device level, while simultaneously maintaining good optical outcoupling properties, these advanced materials systems and engineering solutions may enable the energy efficient adaptation of existing III-V LED dies into viable chips and devices. Furthermore, these advanced materials solutions should not require a substantial change to the complex epitaxial growth chemistry used to commercially produce these devices.

Grant applications must represent viable thermal management materials systems that: (1) can substantially increase the current carrying capacity of the substrates without altering their optical properties; (2) are practical to manufacture – considerable research has already been completed resulting in the predominance of III-V materials epitaxially grown on sapphire (AlO<sub>3</sub>) or silicon carbide (SiC) substrates for HB LEDs; and (3) will ultimately allow the design of devices that exceed existing performance limits of about 100 lumens per watt in packages exceeding 5 Watts of input power.

Questions – Contact James Brodrick ([james.brodrick@hq.doe.gov](mailto:james.brodrick@hq.doe.gov))

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## 25. NEUTRON, ELECTRON, AND PHOTON BEAM INSTRUMENTATION

The Department of Energy supports a number of large-scale, national user facilities that provide intense beams of photons, neutrons and electrons for the characterization of materials. **Grant applications are sought only in the following subtopics:**

**a. Neutron Facilities**—As a unique and increasingly utilized research tool, neutrons have made invaluable contributions to the physical, chemical, and biological sciences. The Department is committed to enhancing the operation and instrumentation of its present and future neutron science facilities so that their full potential is realized.

Grant applications are sought to develop improved neutron detectors and associated electronics needed for DOE’s existing and proposed steady-state and pulsed neutron scattering facilities (References 1-2, 5). New detectors must represent substantial improvements in one or more of the following parameters: efficiency at short wavelengths, high counting rate capability, high spatial resolution in one or two dimensions, cost per unit area, or adaptability to unique geometries. Detectors for pulsed neutron applications must be able to identify the time of arrival of each neutron. All detectors must have low intrinsic dark count rates and low sensitivity to gamma radiation.

Grant applications are also sought to develop novel or improved neutron optical components for use in neutron scattering instruments (References 2-3, 5). Such components include, but are not limited to, neutron choppers, neutron guides, neutron lenses and focusing mirrors, neutron monochromators, or neutron polarization devices including  $^3\text{He}$  polarizing filters. Applications are also sought for novel use of such components in neutron scattering instruments.

Questions – Contact Helen Kerch ([helen.kerch@science.doe.gov](mailto:helen.kerch@science.doe.gov))

**b. Electron Beam Microcharacterization Facilities**—The Department of Energy supports four collaborative research centers for electron beam microcharacterization of materials. These tools are important in the

## FY 2006 Topics

materials and biological sciences and are used in numerous research projects funded by the Department. Innovative instrumentation developments offer the promise of radically improving the capabilities of electron beam microcharacterization and thereby stimulate new innovations in materials science. Grant applications submitted to this subtopic must address improvements in electron beam instrumentation capabilities beyond the present state-of-the-art.

Grant applications are sought to develop stages, holders, and/or detectors with new capabilities for quantifying data and collection efficiency in electron beam instruments. Areas of interest include: (1) extremely stable holders and stages that allow long exposure/analysis times, with accurate tilting and alignment capability (to an angle accuracy  $\pm 0.005$  degrees on two axes while maintaining eucentricity to within 20 nm); (2) fast CCD camera systems that allow electron imaging exposure times in the millisecond range and kHz frame rates; (3) high sensitivity electron imaging systems based on CCD technology that provide 16 bit dynamic range or better over large areas; and (4) improved electron and x-ray detectors that are robust and not susceptible to electron beam damage. Proposed approaches for electron detectors must show suitability for either low- or high-energy electrons, and address one or more of the following three aspects: high quantum efficiency, high spatial resolution, and high temporal resolution. Proposed approaches for x-ray detectors should show significant improvement in sensitivity or spectral resolution for elemental analysis in electron microscopes.

Grant applications are also sought to develop stages and holders with new capabilities for *in situ* experiments or sample manipulation in the transmission electron microscope. Stages and/or holders must provide for one or more of the following: (1) application of magnetic field up to 5000 Oe in the plane of the specimen, with capability to rotate field orientation in the specimen plane with respect to the sample; (2) manipulation or measurement of the sample using a 4-probe nanomanipulator, including capability to measure deflection or strain, or capability to apply electric fields or current; and (3) precision control of specimen temperature (to an accuracy of  $10^\circ\text{C}$  in the range 5-2000K), ambient gas pressure and flow rate (to within several percent for each), and alignment (to an angle accuracy  $\pm 0.005$  degrees on two axes).

Grant applications are also sought to develop electron sources for scanning transmission electron microscopy with brightness on the order  $10^9$  Amp/cm<sup>2</sup>/steradian or higher. Current sources are based on tungsten emitters, and it is hoped that higher brightness can be achieved with new materials and designs. Proposed electron sources must be suitably robust for practical applications, have long lifetimes (greater than 6 months), and offer a significant increase in brightness over existing sources.

Grant applications are also sought for systems for automated data collection, processing, and quantification. Systems should include hardware and platform-independent software for data collection and visualization, including automated measurement and mapping of crystallography, internal magnetic or electric field, or strain, and for multi-spectral analysis. Software and quantification routines for image reconstruction and for interpretation of interference patterns/holography are encouraged.

Finally, grant applications are sought for extremely stable power supplies to improve lens stability in electron beam instruments. Power supplies should be capable of producing 15 amperes with current stability exceeding 0.1 ppm, or 5 amperes with current stability exceeding 0.05 ppm, and should exhibit voltage stability of 0.1 ppm in the range of 1 kV to 200kV.

Questions – Contact Dean Miller ([miller@anl.gov](mailto:miller@anl.gov))

**c. Synchrotron Radiation Facilities**—The DOE supports collaborative research centers for synchrotron radiation science. Synchrotron radiation has become a ubiquitous tool across a broad area of forefront science. However, with advances in the brightness of synchrotron radiation sources, a wide gap has developed between the ability of these sources to deliver high photon fluxes and the ability of detectors to measure the resulting

## FY 2006 Topics

photon, electron, or ion signals. At the same time, advances in microelectronics engineering that are becoming available should make it possible to increase data rates by orders of magnitude, and to increase energy and spatial resolution. With the development of fourth-generation x-ray sources with femtosecond pulse durations, there will be a need for detectors with sub-picosecond time resolution.

Grant applications are therefore sought to develop new detectors for synchrotron radiation science across a broad range of applications. Areas of interest include: (1) area detectors for diffraction experiments; (2) area detectors for readout of electron and ion signals; (3) detectors capable of ultra-high temporal resolution; (4) high resolution imaging detectors; (5) detectors for high rate fluorescence spectroscopy; and (6) detectors for high energy fluorescence spectroscopy.

Questions – Contact Roger Klaffky ([roger.klaffky@science.doe.gov](mailto:roger.klaffky@science.doe.gov))

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## 26. MATERIALS FOR ADVANCED NUCLEAR ENERGY SYSTEMS

The Generation IV nuclear energy initiative is an international collaboration to identify, assess, and develop sustainable nuclear energy technologies that are competitive in most markets, while further enhancing nuclear safety, minimizing the nuclear waste burden, and further reducing the risk of proliferation (reference 1). Many

## FY 2006 Topics

nuclear energy systems have been proposed to advance the goals of the Generation IV program (see references 2-8), including designs that use liquid-metal coolants such as sodium and lead, gas coolants such as helium, water coolants such as supercritical water, and molten salt coolants. For these systems, operation at higher temperature has been identified as a means to improve economic performance and to support the thermochemical production of hydrogen. However, the move to higher operating temperatures will require the development and qualification of advanced materials to perform in the more challenging environment. As part of the process of developing advanced materials for these reactor concepts, a fundamental understanding of materials behavior must be established and a database that defines the critical performance limitations of these materials under irradiation must be developed. A recent workshop details many of the research challenges for higher temperature materials associated with proposed Generation IV systems (reference 9). **Grant applications are sought only in the following subtopics:**

**a. Advanced Radiation Resistance Ferritic-Martensitic Alloys**—Because of their resistance to void swelling, 9 Cr and 12 Cr ferritic-martensitic steels are considered prime candidates for intermediate temperature reactors such as the proposed liquid metal and supercritical water concepts operating in the temperature range of 400-750°C. However, many ferritic-martensitic steels are limited by poor higher temperature creep strength, typically degrading at temperatures greater than 550-600°C (reference 10). Grant applications are sought to improve the creep strength of 9 Cr and 12 Cr ferritic-martensitic steels through alloying, dispersion strengthening, or precipitation hardening. Innovative alloys with protective coatings are also of interest. Proposed approaches must provide for (1) isotropic creep properties with strength greater than that of Sandvik HT9 steel, (2) a ductile to brittle transition temperature less than room temperature, and (3) a minimum plane-strain fracture toughness of  $0.25\sigma_y$ . Alloying elements that act as neutron poisons (e.g., boron) or that become highly activated in a neutron spectrum (e.g., cobalt) must be minimized or eliminated. Because the ferritic-martensitic steels likely would be used in conjunction with sodium-cooled, lead- or lead-bismuth-cooled, or supercritical water-cooled reactor concepts, approaches that optimize corrosion performance while achieving improved high temperature strength would be considered high priority. Lastly, approaches that also address irradiation performance are strongly encouraged.

Questions – Contact Sue Lesica ([sue.lesica@hq.doe.gov](mailto:sue.lesica@hq.doe.gov))

**b. Advanced Refractory, Ceramic, Ceramic Composite, or Coated Materials**—Some Generation IV concepts aim for very high temperature (>900°C) operation. However, with the exception of limited data on SiC-based systems, the radiation resistance of construction materials subjected to very high temperatures has not been identified or proven. Grant applications are sought to develop advanced refractory, ceramic, ceramic composite, or coated materials that can meet the very demanding conditions required to operate at temperatures greater than 900°C in a fast spectrum nuclear energy system. For these conditions, the materials should have low thermal expansion coefficients, excellent high temperature strength, excellent high temperature creep resistance, and good thermal conductivity. For post-irradiation handling at lower temperatures, sufficient room temperature fracture toughness must be maintained. Additionally, the materials need to be easily fabricated and capable of being joined. Because the reactors operating in this temperature regime are expected to be helium cooled, the materials must have low erosion properties in flowing helium and be able to survive an air ingress condition. Because sustainable nuclear energy systems are likely to be based on fast spectrum systems, the materials must avoid low atomic mass components such as hydrogen and carbon. Because the high temperature strength and corrosion resistance may be difficult to achieve with a single material, composite or coated systems may be required. Finally, because sustainable nuclear energy systems may be based on fast spectrum (i.e., fast flux) designs, materials intended for fast reactor concepts should minimize the use of low atomic mass components such as hydrogen and carbon.

Questions – Contact Sue Lesica ([sue.lesica@hq.doe.gov](mailto:sue.lesica@hq.doe.gov))



## FY 2006 Topics

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\* Abstracts of papers and ordering information available through ASME at:  
<http://store.asme.org/category.asp?catalog%5Fname=Conference+Papers&category%5Fname=Tenth+International+Conference+on+Nuclear+Engineering&Page=1>. Search by Paper No. in citation above.)

## PROGRAM AREA OVERVIEW NUCLEAR ENERGY, SCIENCE AND TECHNOLOGY

Continued use of nuclear power is an important part of the Department’s strategy to provide for the Nation’s energy security, as well as to be responsible stewards of the environment. Nuclear energy currently provides over 20 percent of the U.S. electricity generation and will continue to provide a significant portion of U.S. electrical energy production for many years to come. Also, nuclear power in the U.S. makes a significant contribution to lowering the emission of gases associated with global climate change and air pollution.

The Office of Nuclear Energy, Science and Technology (NE) enables the Department of Energy to provide the technical leadership necessary to address critical domestic and international nuclear issues by administering

## FY 2006 Topics

research and development and technical assistance in the following general areas: (1) the Generation IV Nuclear Energy Systems Initiative seeks to develop and demonstrate one or more Generation IV nuclear energy systems that offer advantages in the areas of economics, safety and reliability, sustainability, and could be deployed commercially by 2030; (2) the Nuclear Energy Research Initiative (NERI) Program addresses key issues affecting the future of nuclear energy in order to preserve U.S. nuclear science and technology leadership; (3) the Radioisotope Power Systems Program develops new state-of-the-art radioisotope power systems to support the NASA space missions and terrestrial applications for other agencies; (4) the Nuclear Energy Plant Optimization (NEPO) Program conducts research to assure the continued safe and reliable operations of over 100 of the Nation's nuclear power plants; (5) the University Reactor Fuel and Educational Assistance Program is designed to help retain the U.S. nuclear engineering capability for conducting nuclear research, addressing pressing nuclear environmental challenges, and preserving the nuclear energy option; (6) the Isotope Production Program produces and sells hundreds of stable and radioactive isotopes that are widely used by domestic and international customers for medicine, industry and research applications; and (7) the Advanced Fuel Cycle Initiative supports the growth of nuclear energy by developing and demonstrating technologies that enable transition to a stable, long-term, environmentally, economically and politically acceptable advanced fuel cycle.

For additional information regarding the Office of Nuclear Energy, Science and Technology priorities, [click here](#).

## 27. ADVANCED TECHNOLOGIES FOR NUCLEAR ENERGY

Nuclear power provides over 20 percent of the U.S. electricity supply without emitting harmful air pollutants, including those that may cause adverse global climate changes. New methods and technologies are needed to address key issues that affect the future deployment of nuclear energy and to preserve the U.S. leadership in nuclear technology and engineering. This topic addresses several of these key technology areas: improvements in nuclear reactor technology for existing reactors and evolutionary designs, advanced instrumentation and control (I&C) for very high temperature reactor applications, advanced I&C for use in high radiation environments, and advanced core/reactor physics computer simulations and modeling for Generation IV reactor designs. **Grant applications are sought only in the following subtopics:**

**a. New Technology for Improved Nuclear Energy Systems**—Improvements and advances are needed for reactor systems and component technologies that ultimately would be used in the design, construction, or operation of existing and future nuclear power plants and Generation IV nuclear power systems [See References]. Grant applications are sought: (1) to improve and optimize the nuclear power plant and its systems, along with component instrumentation and control, by developing and improving the reliability of advanced instrumentation, sensors, controls, and by increasing the accuracy of measuring of key reactor and plant parameters; (2) to improve monitoring of plant equipment performance and aging, using improved diagnostic techniques for in-service and non-destructive examinations; (3) for advanced instrumentation, sensors, and controls for very high temperature Generation IV reactor designs that can withstand temperatures in excess of 1000° C; (4) for advanced instrumentation, sensors, and controls for very high irradiation environments that will be encountered in advanced evolutionary and Generation IV reactor designs; (5) for advanced reactor/core computer simulation methods including advanced reactor design model code development; coupled/parallel thermal-hydraulic-reactor physics tools; safety and performance evaluation methods; and engineering calculations for *new* Generation IV reactor designs, reactors, major reactor components, and reactor core and fuel assemblies; and (6) to develop light-water-reactor, spent-reactor-fuel separations technology and devices that are compatible with the UREX+ process [see reference 6] and allow for fission product separation of highly radioactive, low-atomic-mass isotopes from spent transuranic and minor actinide wastes (e.g. Pu, Np, Am, Cm, etc) without explicit plutonium separation.

## FY 2006 Topics

Grant applications that address the following areas of investigation are **NOT** of interest and will be declined: concepts for complete or partial reactor plant designs; generalized thermal-hydraulics analysis (e.g. CFD or two-fluid codes) and probabilistic risk assessment tools or methods; reactor/core computer simulation methods for existing light water reactor designs, nuclear power plant security, or building/containment enhancements; and NRC safety experiments, testing, licensing, and site permit issues. In addition, grant applications that deal with nuclear materials, chemistry, and/or corrosion research are also not of interest for this topic and should be submitted instead under Topic 26.

Questions – Contact Madeline Feltus ([madeline.feltus@hq.doe.gov](mailto:madeline.feltus@hq.doe.gov))

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## PROGRAM AREA OVERVIEW OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

The mission of the Office of Energy Efficiency and Renewable Energy (EERE) is to strengthen America's energy security, environmental quality, and economic vitality through public-private partnerships that enhance energy efficiency and productivity; strengthen the U.S. manufacturing sector with advances in innovation; bring clean, reliable, and affordable energy technologies to the marketplace; and make a difference in the everyday lives of Americans by enhancing their energy choices and their quality of life.

In order to accomplish this mission, EERE has streamlined and integrated its program and business management by creating 11 programs to most effectively address the needs of the industry, transportation, buildings and power sectors: Biomass; Buildings; Distributed Energy and Electricity Reliability; Federal Energy Management; FreedomCar and Vehicle Technologies; Geothermal; Hydrogen, Fuel Cells, and Infrastructure Technologies; Industrial Technologies; Solar Energy Technology; Wind and Hydropower Technologies; and Weatherization and Intergovernmental.

## FY 2006 Topics

One of EERE's core mission priorities is to engage and partner with the small business technology sector, in so doing, "leapfrog the status quo" by facilitating the development of new technologies that will dramatically reduce or end dependence on foreign oil; increase the viability and deployment of renewable energy technologies; increase the reliability and efficiency of electricity generation, delivery, and use; increase the efficiency of buildings and appliances; and increase the efficiency/reduce the energy intensity of industry.

It is estimated that the energy technologies and practices supported by the EERE programs have saved Americans billions of dollars in energy costs over the past decade. These savings are projected to dramatically increase as emerging and new energy technologies are developed and commercialized. These energy savings are accompanied by parallel reductions in emissions and pollutants that affect human health and in the production of greenhouse gases. The EERE program in renewable energy has advanced the state of technologies in such areas as solar, wind, and biomass to the point where renewables have been projected to supply as much as 28 percent of the Nation's energy by 2030.

For additional information regarding the Office of Energy Efficiency and Renewable Energy priorities, [click here](#).

## 28. ADVANCED MATERIALS FOR NEW ENERGY CARRIERS, SERVICES, AND PRODUCTS

Advanced materials play a fundamental role in technology advance, underpinning the development of new technological capabilities as well as whole new industries for the transformation and production of new energy carriers, services, and products. **Grant applications are sought only in the following subtopics:**

**a. Advanced Materials for Hydrogen Storage**—The on-board storage of hydrogen as a fuel for vehicles will require the identification of new materials with high storage capacities for hydrogen; i.e., with high gravimetric and volumetric hydrogen capacities (greater than 6 wt.% hydrogen and greater than 0.045 kg hydrogen per liter). Further details on the requirements of hydrogen storage systems, including energy density, charge and discharge rates, etc., can be found at: [http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/freedomcar\\_targets\\_explanations.pdf](http://www.eere.energy.gov/hydrogenandfuelcells/pdfs/freedomcar_targets_explanations.pdf). Grant applications are sought for the discovery and synthesis of new, high-hydrogen-capacity storage materials including, but not limited to, complex metal hydrides, carbon-based materials, high-surface-area hydrogen sorbents, and chemical hydrides. Of particular interest are advanced combinatorial methods that have the ability to reactively expose arrays of candidate material compositions to hydrogen-containing environments and the capability to detect and measure the quantity of hydrogen absorbed by each individual material composition, in order to compare the hydrogen capacities of the material compositions within the array. Hydrogen capacity combinatorial analyses should be performed in the shortest possible time, consistent with the accuracy of results, and should cover the temperature and hydrogen pressure ranges of 20-200°C and 1-100 atmospheres, respectively.

Grant applications are also sought to develop novel thermal management approaches to meet the challenging heat-transfer requirements in the charging and discharging of hydrogen storage systems (such as metal hydrides) for the vehicular generation of hydrogen fuel. Approaches of interest include, but are not limited to, novel thermal interface materials, unique integrated designs, new concepts (such as supporting hydrides on high-conductivity structures), using heat transfer fluids for effective heat and mass transfer.

Questions – Contact Matthew Kauffman ([matthew.kauffman@hq.doe.gov](mailto:matthew.kauffman@hq.doe.gov))

**b. Thermoelectric Materials for Recovery of Waste Heat from Industrial Streams**—The exit streams from processes used to manufacture metals and other materials often have substantial embodied energy that cannot be

## FY 2006 Topics

cost effectively captured as an energy source. Therefore, grant applications are sought to develop advanced thermoelectric materials and systems for economically recovering low and medium grade industrial waste heat from the gases and liquids in exit streams (including hot gas cleanup and dehydration of liquid waste streams). Grant applications should target processes in one or more of the following energy-intensive basic industries: chemicals, steel, pulp and paper, glass, aluminum, and metal casting.

Questions – Contact Sara Dillich ([sara.dillich@hq.doe.gov](mailto:sara.dillich@hq.doe.gov))

**c. Seals for High Temperature Applications**—Seals that operate at temperatures greater than 225°C and at pressures greater than 5,000 psi are needed for a number of applications: bearings in bits and pumps, closure of instrumentation packages, feed through of telemetry/power cables, etc. Currently used seals (o-rings, rubber boots, etc.) exhibit severe failures above 200°C – above this temperature most of these devices are subject to hydrolysis. Advanced seals such as metal o-rings, Kalrez, etc. have shown mixed results. The presence of harsh constituents (chlorides, hydrogen sulfide, drilling mud, etc.) only adds to the sealing problems. Another problem is that the testing and rating of such parts is typically done at high temperature or high pressure, but not both at the same time. Grant applications are sought for a systematic approach to the development of high temperature seals and should include: (1) an investigation of the performance of existing commercial-off-the-shelf (COTS) parts (o-rings, boots, adhesives, etc.), at elevated pressures and temperatures, to determine their limits and to suggest modifications (the testing should include thermal and pressure cycling as well as static conditions); (2) a retest of the COTS parts after advanced coatings are applied (e.g., o-rings with Parylene coatings), to determine the level of improved performance, if any, provided by the coatings; and (3) the development of new seal materials/concepts; and (4) a clear explanation of the intended application (i.e. geothermal drilling, industrial processing, etc.)

Questions – Contact Raymond Lasala ([raymond.lasala@ee.doe.gov](mailto:raymond.lasala@ee.doe.gov))

**d. Improved Oxide Ceramic Matrix Composite Development for Industrial and Gas Turbine**—Ceramic Matrix Composite (CMC) materials have been tested successfully for over 65,000 hours in field evaluations at industrial gas turbine end user sites. Because of the harsh condition, these materials require protection from either an environmental barrier coating (EBC) or by a thick thermal protection system (TPS). Although current EBCs afford a measure of protection, they are prone to degradation in service, because they contain silicon-based constituents. The downside of the oxide-based TPS systems is that they are not easy to apply (as they are typically thick thermal barrier coatings), which could debond under cyclic operating conditions.

An examination of the literature reveals the existence of oxide-based materials (e.g. YAG – yttrium aluminum garnet, etc.) with superior mechanical properties and microstructural stability, compared to existing SiC/SiC or oxide/oxide CMCs. Using these materials, a compatible interfacial coating between the fiber and matrix could be incorporated to enhance mechanical properties. This novel CMC would not require an environmental barrier coating (EBC) or thermal protection system (TPS) and would be cost effective compared to SiC/SiC/EBC or oxide/oxide/TPS. Therefore, grant applications are sought to develop a CMC material with superior high temperature (over 1200°C) mechanical properties and oxidation resistance in gas-turbine-hot-section environments and aggressive industrial process environments, compared to state-of-the-art SiC/SiC or oxide/oxide CMCs. The new CMC must be cost effective, require no coatings for environmental and/or thermal protection, and have a life expectancy of 30,000 hours in gas turbine applications. Grant applications should address the preparation of test specimens for mechanical property evaluation and durability testing in furnaces and in simulated gas turbine or industrial environments. The data collected should be compared with those of existing state-of-the-art SiC/SiC (with EBC) and oxide/oxide (with TPS) CMCs.

Questions – Contact Merrill Smith ([merrill.smith@hq.doe.gov](mailto:merrill.smith@hq.doe.gov))



## FY 2006 Topics

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## 29. ADVANCED MATERIALS FOR LIGHTWEIGHT VEHICLES

Advanced materials play a fundamental role in all sectors of the U.S. economy, underpinning the development of new technological capabilities, as well as whole new industries, for the transformation and production of new energy carriers, services, and products. In particular, lightweight materials in automobile and truck structures can provide significant fuel savings. In addition, the material must be cost-effectively fabricated, be able to withstand the service environment, and be recyclable. The following subtopics have been identified as critical areas for the development of advanced materials for the transportation sector. **Grant applications are sought only in the following subtopics:**

**a. Cost-Effective Coating Systems for Corrosion Protection of Mg Alloys in Automotive and Truck Applications**—The cost of corrosion protection for Mg components, made by high-rate, high-volume manufacturing processes such as casting and extrusion, is a significant portion of the overall product cost. In many cases, it is one of the limiting barriers preventing the wide-scale use of this lightweight material. Grant applications are sought to develop cost-effective coating technologies that can protect Mg alloys in automotive and truck components that are exposed to the road environment, such as structural parts, outers, and wheels. Areas of interest include, but are not limited to, the development of: (1) a low-cost conversion treating process, using either an electroless immersion process or a low-cost anodizing process, that can protect Mg against general and galvanic (contact) corrosion when used with a topcoat; (2) robust surface treating/coating technologies for joining components that would come into contact with Mg alloys – which could include coating processes for steel- or aluminum-based washers, nuts, or bolts; and (3) high-strength, high-toughness Al alloys that are compatible with Mg alloys used in exterior applications. Grant applications must: (1) include procedures to evaluate the effectiveness of the new coatings/products, using both standard lab testing methodologies as well as in-vehicle prototype demonstration; (2) indicate familiarity with the technical requirements of Mg coating systems and explain the guiding principle(s) for the proposed new processes; and (3) demonstrate that the technologies, with appropriate design considerations and further development, could be cost-effectively incorporated into the high-rate, high-volume manufacturing of commercial passenger vehicles and trucks.

Questions – Contact Joseph Carpenter ([joseph.carpenter@ee.doe.gov](mailto:joseph.carpenter@ee.doe.gov))

**b. Architecturally-Improved Ultra-Light Powertrain Concepts for Internal Combustion Engines**—Of all the vehicle subsystems which must be mass-reduced, the engine and driveline remain the most obstinate in terms of their ability to significantly contribute to an improved fuel economy for the vehicle. Although new block and head materials (e.g., aluminum or magnesium) have provided minor reductions in engine mass, no approaches have addressed internal and moving components such as the crankshaft, connecting rods, and valvetrain. Mass reductions of moving components are doubly valuable because these mass reductions also would lead to frictional reductions within the engine, thereby further improving efficiency. Grant applications are sought for new, fundamental approaches to the mass reduction of engine and driveline components. Approaches of interest include structural improvements, the incorporation of novel or traditional lightweight materials for internal and moving components, and the integration of hybridization elements such as electric machines. Grant applications must demonstrate: (1) a capacity to reduce engine, transmission, driveline package mass by up to 30% over present systems; (2) that with appropriate design considerations and further development, the approaches could be cost-effectively incorporated into the high-rate, high-volume manufacturing of passenger vehicles; and (3) consistency with the current Otto and Diesel engine architectures – new engine or transmission concepts that are not compatible with current engines and transmissions will not be accepted.

Questions – Contact Joseph Carpenter ([joseph.carpenter@ee.doe.gov](mailto:joseph.carpenter@ee.doe.gov))

## FY 2006 Topics

**c. Recycling Automotive and Truck Materials**—Innovative, lightweight materials are playing a key role in helping to improve vehicle fuel economy and safety. However, these materials can also present special challenges to recycling. Grant applications are sought to develop technology for the sustainable recycling of current and future automotive and truck materials. Grant applications must identify a specific issue and/or anticipated problem area(s) associated with the ability to recycle the material, and then outline a technical solution or approach for resolving the identified issue. Areas of interest include, but are not limited to, technologies for: (1) the separation and recovery of specific constituents from automotive materials (including shredder residue) that might otherwise be landfilled at end-of-life (e.g., improvements in mechanical separation technologies, development of advanced separation technologies such as high-speed materials identification and sorting, and the development of bulk physical separation processes including density and gravity separation, froth flotation, and electro-static processing); (2) the effective utilization and/or conversion of specific materials (or fractions of materials from shredder residue such as fines, polymer concentrates, etc.), which might otherwise be landfilled, to valued-added recycled products; (3) thermo-chemical conversion (e.g. pyrolysis, hydrolysis, gasification) of polymeric and other organic based automotive materials to saleable chemicals and fuels; and (4) the removal and control of residual contamination (by such substances as PCBs, PBDEs, and heavy metals) from materials recovered from shredder residue.

Questions – Contact Joseph Carpenter ([joseph.carpenter@ee.doe.gov](mailto:joseph.carpenter@ee.doe.gov))

**d. On-Line/Real-Time Nondestructive Evaluation (NDE) of Vehicle Components**—NDE is used throughout the auto industry to inspect numerous vehicle components and processes: complex castings, joining (e.g., welding and adhesion), metal forming, etc. Grant applications are sought to develop highly reliable, cost effective, and efficient NDE methods, which are tailored to the unique production environment of the automotive industry. Proposed systems must be reliable, robust, and require minimal training for proper operation – ideally, they would work on-line and in real time. Successful systems could significantly reduce the present practice of over-designing components to assure passenger safety; an optimized design, which could be confirmed using a trusted NDE system could utilize significantly lighter vehicle components. Grant applications should (1) focus on the primary NDE concerns of the industry, namely, evaluation of complex castings, evaluation of material bonding (e.g., welds including RSW, adhesive bonding, etc.), and inspection of thin sheets and (2) show that the concept(s) to be addressed, with further development, could be cost-effectively incorporated into the high-rate, high volume vehicle manufacturing environment by operators with minimal training.

Questions – Contact Joseph Carpenter ([joseph.carpenter@ee.doe.gov](mailto:joseph.carpenter@ee.doe.gov))

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## FY 2006 Topics

- *Automotive Propulsion Materials*
- *Automotive Lightweighting Materials R&D*
- *Heavy Vehicle Propulsion Materials Program*
- *High Strength Weight Reduction Materials*

### 30. ADVANCED MATERIALS AND PROCESS TECHNOLOGIES

Advances in materials and process technologies are critical to the U.S. in maintaining technological competitiveness and energy and economic security in the world today. Such advances will underpin the development of new capabilities for energy efficiency and renewable energy as well as whole new industries for the transformation and production of new energy carriers, services, and products. The following have been identified as critical areas for the development of advanced materials and processes.

**a. Advanced Bio-Based Materials and Bioproducts**—Materials derived from lignocellulosics, as well as resins from the chemical or biological conversion of biomass components, can serve as value-added co-products from an advanced lignocellulose-based biorefinery. Biologically based feedstocks also can be the source of other co-products such as solvents, cleaning agents, and formulations for polymers and coatings. In order for such value-added co-products to become a reality, further research and development will be needed to facilitate the production of new materials or high performance formulations derived from fibrous or resinous biomass. Grant applications are sought to develop: (1) technology for the conversion of fibrous lignocellulose/cellulose (for fiber) high molecular weight polymers to high performance materials – of particular interest are methods for improving the strength of the interactions between hydrophilic lignocellulosic materials and the more hydrophobic resins; (2) high performance formulations of biobased products for cleaning, coating, and pollutant removal applications, without the emission of hazardous pollutants; and (3) corrosion and abrasion resistant materials for use in the processing of aggressive streams associated with the pretreatment of lignocellulosic feedstocks and the thermochemical conversion of black liquor.

Questions – Contact Mark Decot ([mark.decot@hq.doe.gov](mailto:mark.decot@hq.doe.gov))

**b. Wind Turbine Materials for Extreme Environments**—A wide range of wind turbine systems are being installed in extreme environments, which may include high and low temperatures, high humidity, wind-blown dust and sand, and the effects of corrosion (in offshore environments). These environments can significantly decrease wind turbine lifetime: extremes of heat and cold can have a varying range of effects on most of the materials used in constructing the wind turbine; high temperatures and humidity levels can reduce fiberglass blade strength; and corrosive offshore environments can damage generators, power converters, towers, and support structures. Grant applications are sought to develop innovative materials, coatings, and treatments that can improve the strength and endurance of wind turbines in these extreme environments, with a minimal impact on overall equipment costs. The Phase I effort should lead to a demonstration of the new material in Phase II, in simulated or actual extreme environments.

Questions – Contact Dennis Lin ([dennis.lin@ee.doe.gov](mailto:dennis.lin@ee.doe.gov))

**c. Renewable Energy and Production of Fresh Water**—In the developing world, the rapid growth of population, along with attendant agricultural demands, is placing a burden on available water resources. In the United States as well, much of the West and Midwest is suffering the effects of a prolonged drought. Many of these regions of growing demand and drought are closely correlated with the potential for significant untapped renewable energy, including wind, solar, geothermal, and biomass. The proximity of the growing demand and untapped power resource offers a significant opportunity to develop and use renewable technologies for

## FY 2006 Topics

advanced desalination, reclamation, and recycling techniques. For example, in many of these regions large resources of sea water and saline aquifers are available. Grant applications are sought to develop advanced cost-effective concepts for desalination, reclamation, and recycling using chemical, thermal, mechanical, or electrical energy from renewable sources. Approaches should be targeted toward high volume, clean water production, pumping, irrigation, and storage using renewable energy sources. Designs must take into account variable demand and the intermittent nature of some renewable power sources. Systems should be optimized based on the life cycle cost of the total system (including required power and generated pure water). The Phase I effort should lead to hardware development, fabrication, and testing of a prototype system under Phase II, with a demonstration project to follow in a potential Phase III.

Questions – Contact Dennis Lin ([dennis.lin@ee.doe.gov](mailto:dennis.lin@ee.doe.gov))

**d. Natural Gas Alternatives for Manufacturing**—Manufacturers use enormous amounts of natural gas in manufacturing (7.2 trillion cubic feet in 1998) – for process heating, steam generation (boilers), and chemical feedstock purposes – which causes shortages in U.S. domestic natural gas supplies. Research is needed to develop alternative approaches to supplying fuels for chemical feedstocks, as well as new technologies to reduce the demand for process heating and steam generation. Therefore, grant applications are sought to develop technologies, innovative processes, or process modifications for upgrading the quality or fuel value of syngas. Areas of interest include: (1) novel processes for fuel enrichment, blending, modification, or cleaning undesirable constituents from the syngas, and (2) novel techniques to make the gas more attractive for such industrial applications as combustion or feedstock use, as opposed to power production. Approaches must be suitable to applications in industrial settings such as in the chemical, steel, forest product, and glass industries. Of particular interest are grant applications that offer the potential to improve the state of the art, be more cost-effective than current techniques of syngas upgrading, and be applicable to broad segments of industry.

Questions – Contact Dennis Lin ([dennis.lin@ee.doe.gov](mailto:dennis.lin@ee.doe.gov))

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## 31. RENEWABLE ENERGY SOURCES

Renewable energy technologies have achieved significant advances in recent years, but further improvements are needed if they are to realize their full potential. This topic addresses solar photovoltaic (PV) technologies, systems for concentrating solar power, and on advanced geothermal technologies. Grant applications must clearly demonstrate the ability of the applicants to proceed to hardware development, fabrication, testing, and manufacture of technologies. **Grant applications are sought only in the following subtopics:**

**a. Photovoltaic Module Packaging, Interconnects, and Reliability Verification**—Grant applications are sought to develop cost-effective module packaging (encapsulation) to protect PV devices from water. Today, heavy and costly encapsulation schemes are used, which require replacement or modification to reduce cost. One area of interest is to use directly deposited barrier-coatings to protect the PV devices.

Grant applications are also sought for new cost-effective approaches for connecting the PV modules to an external circuit. This usually requires some means of aggregating cell power into a single busbar, a means of exiting the module package, and an external connector such as a j-box. Today, the components used to accomplish these functions have relatively high associated costs. Approaches of interest must demonstrate reductions in cost and complexity, taking into account full system production and installation.

Lastly grant applications are sought to develop innovative technical approaches for diagnosing the reliability and performance of an individual PV module without removing it from a system. Approaches of interest include embedded visual sensors that display color or numerical data, the transmission of embedded sensor data by power line carrier or wireless data transmission, or the use of external sensors for remote diagnostics. The data gathered must provide information on system performance in real time, sufficient to determine whether specific modules are behaving within the predicted range.

Questions – Contact Alec Bulawka ([alec.bulawka@hq.doe.gov](mailto:alec.bulawka@hq.doe.gov))

**b. Improved Thin Film Materials, Modules, and Material Recovery**—Two leading thin film technologies used in PV systems, CuInSe<sub>2</sub> and CdTe, use relatively rare elements - indium and tellurium, respectively – that could constrain very large scale production (e.g. in the TeraWatt range). Other components, particularly cadmium, raise concerns about toxicity and require cradle-to-grave tracking and management to ensure public health and to reassure the public (despite the fact that detailed technical analyses have demonstrated no significant risk in comparison to other sources of cadmium in the environment). To address these issues, grant applications are sought to develop: (1) effective designs, systems, and hardware to enable the cost-effective recovery of valuable materials such as indium and tellurium for reuse by the PV industry and to simultaneously clean waste streams and end-of-life wastes of toxic materials such as cadmium and selenium; (2) new thin film materials, which are not rare nor toxic, for use in high-efficiency, low-cost PV systems – of particular interest are new inorganic direct-band-gap thin-film semiconductors that do not have materials availability or toxicity issues, yet still provide high performance at potentially low cost; and (3) new transparent conductive materials, such as innovative p-type transparent conducting oxides, to carry electricity over the front surface of the module to the top junction of the thin film cell. These new transparent conductive materials, which would replace presently-used oxides (e.g., tin oxide, cadmium stannate, and zinc stannate), must be amenable to cost-effective application at high deposition rates (with high uniformity and reliability, and, preferably, at relatively low temperatures) on thin-film PV modules using possibly new, n-type absorbers.

Questions – Contact Alec Bulawka ([alec.bulawka@hq.doe.gov](mailto:alec.bulawka@hq.doe.gov))

**c. Innovative Reflector Materials and Designs for Concentrating Solar Power Systems**—Mirror systems – troughs, dishes, and heliostats – typically account for up to half or more of the total cost of concentrating solar

## FY 2006 Topics

power systems used for power or fuels production. Grant applications are sought to develop technology leading to significant reductions in cost, and improvements in the performance, of these mirror systems. Areas of interest include (1) innovative reflector materials and systems that can reduce capital costs, as well as operations and maintenance costs, while maintaining or increasing performance (e.g. new coatings, thin glass materials, polymers, self-cleaning materials, etc.), and (2) innovative designs, using either current or innovative materials, that can significantly reduce costs compared to current systems and designs.

Questions – Contact Raymond LaSala ([raymond.lasala@hq.doe.gov](mailto:raymond.lasala@hq.doe.gov))

**d. Non-Rotating Drilling for Geothermal Energy Development**—Drilling is a significant cost for geothermal development. With current drilling techniques, energy is transmitted to the rock face by drill string rotation or by pumping drilling fluid to power a downhole mud motor. Grant applications are sought to develop innovative systems for rock reduction and removal systems in the drilling of geothermal boreholes. For rock reduction, it is permissible to use rotation to supplement rock reduction (e.g., rotary steering). It also is permissible to use hydraulic transmission to provide rock reduction energy to the bit face, so long as it is not used for operating a mud motor with a conventional bit. For rock removal, the system must result in disposable "cuttings"; that is, if the rock is melted or vaporized it must be converted back to an environmentally appropriate end product. Also, if the conventional circulation of drilling fluid is to be used for rock removal, the applicability of this approach must be demonstrated. Lastly, issues of well control and wellbore integrity must be addressed.

The system must be capable of creating borehole diameters from 6½ to 12 ¼ inches, be able to operate at temperatures up to 225°C and downhole pressures up to 10,000 psi, provide a rate of penetration (ROP) greater than 80 feet per hour in hard rock such as Sierra White Granite, and allow for more than 800 feet per trip (better than emerging polycrystalline diamond compact (PDC) bit technology rather than old roller cone bit technology).

Questions – Contact Alec Bulawka ([alec.bulawka@hq.doe.gov](mailto:alec.bulawka@hq.doe.gov))

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## 32. ADVANCED MOTORS, POWER ELECTRONICS, AND SENSORS AND CONTROLS

Advances in materials and designs for advanced electric motors, power electronics, and sensors and controls are opening a variety of opportunities to significantly improve the performance, reliability, and economics of efficient energy use in transportation, buildings, industry, and renewable energy. These include new applications for the conversion of power from electrical-to-mechanical or mechanical-to-electrical forms; power electronics that can operate reliably at higher temperatures; and the integration of sensors and controls that permit continuous response to system changes, improving performance and reducing operations and maintenance costs. Grant applications must clearly demonstrate the ability of the applicants to proceed to hardware development, fabrication, testing, and manufacture of components and devices. **Grant applications are sought only in the following subtopics:**

**a. Advanced Motors**—Passenger transportation will increasingly use electric motor drives in both hybrid and fuel cell vehicles. Hybrid vehicles are a new and rapidly growing segment of the passenger transport market. Fuel cell vehicles are under development to meet mobility needs in the longer term. Both depend on high performance electric motor drives. Grant applications are sought to improve the performance of the electronic motors in these vehicles by: (1) increasing the saliency ratio of permanent magnet (PM) motors, (2) developing improved laminations for PM motors, and (3) developing improved powders for use in bobbin-wound stator motors. Each of these opportunities will be discussed in turn.

(1) The saliency ratio ( $L_q/L_d$ ) is determined by the difference in reluctance (the resistance to magnetic flux) in two magnetic flux paths: the path between the magnets and the path through the center of the magnets. Although the hybrid electric vehicle industry has achieved a high saliency ratio of 2.86 by using interior PMs, further increases will be needed so that the motors can produce a rated power of 55 kW from base speed to 25,000 rpm, with a constant power speed range (CPSR) of 10 or more. Of particular interest is the use of inset surface-mounted permanent magnets. Grant applications are sought for new magnet configurations that would provide saliency ratios higher than now achievable using current technology. These improvements would increase both CPSR and mechanical stability, allowing a high percentage of the motor's duty cycle to be at high speeds, where it can benefit from the higher efficiency provided by the new dual mode inverter control.

(2) The trend for HEV and EV motors is toward high speed operation, which, for interior permanent magnet motors, requires the number and width of the bridges to be increased. Unfortunately, the bridges are undesirable leakage paths that decrease the motor performance. If the bridges could be treated to obtain higher reluctance, the flux leakage through the bridges could be diminished. One possibility is to use laminations whose permeability can be changed through local heat treatments. However, for currently available laminations, the magnetic saturation level of the material is low, and the cost of the material is high. Therefore, grant applications are sought to develop high mechanical strength, high magnetic saturation level, low cost, low-core-loss magnetic laminations that are capable of locally controllable permeability-change properties.

(3) Bobbin-wound stator motors offer a promising alternative to mush wound stators. Current methods for producing these types of stators involve the use of existing compressed powder materials. Although these materials have low core losses, their magnetic saturation level is low, and their cost is still high. Therefore, grant applications are sought to develop improved powders for use in bobbin wound stator motors in an automotive environment.

Questions – Contact Susan Rogers ([susan.rogers@ee.doe.gov](mailto:susan.rogers@ee.doe.gov))

**b. Advanced High Temperature Power Electronics and Controls**—There is a growing demand for advanced power electronics that can operate at high-temperatures for transport, industry, and drilling/logging applications. New materials such as silicon carbide (SiC) are beginning to open opportunities to meet these demands, but

## FY 2006 Topics

attendant circuits and related components to support high temperature operation remain to be developed. As described in the following paragraphs, grant applications are sought to develop: (1) SiC gate driver circuits, (2) technology for increasing the thermal conductivity in the packaging of the power electronics, and (3) electronic components for emerging high temperature technologies.

(1) SiC-based power devices are capable of operating at junction temperatures above 350°C; however, the existing gate drivers for these power devices use silicon (Si) components, which cannot withstand such high temperatures. Therefore, grant applications are sought to develop SiC-based gate drivers that can operate at high temperatures and can be integrated with SiC power devices in the near future. Of particular interest is an all-SiC gate driver that can operate in the temperature range of -50°C to +150°C with minimal or no cooling.

(2) The temperature of the coolant, used to remove heat from the power electronics in HEV applications, is being pushed higher, toward that of the engine coolant. However, at higher coolant temperatures, the usable current, needed by such power semiconductor devices as Insulated Gate Bipolar Transistors (IGBTs), becomes severely limited. The problem is the inefficient heat dissipation capability of existing IGBT power module packaging materials, a problem that becomes even more exaggerated as the die size of IGBT devices decreases due to improvements in device structure. These modules are constructed by bonding the die, substrate, and the base plate together, and then mounting the whole module on a heat sink using thermal interface materials. To better utilize these devices, grant applications are sought to develop new ceramic and/or insulated metal/composite substrates with high thermal conductivity and low coefficient of thermal expansion (CTE), matched to that of the IGBT silicon dies; thermal interface materials with low thermal resistance; and advanced bonding and soldering techniques that can withstand the wide ranges of temperature cycling in automotive applications.

(3) There is a growing demand for high-temperature electronics to control drilling and logging, industrial processes, and automobile and aerospace operations. In order to take advantage of emerging high-temperature technologies in these industries, new high-temperature electronic components suited for such environments need to be commercially developed. Grant applications are sought to develop one or more of the following electronic components for these applications: a 300°C large value capacitor, a 350°C voltage reference, and a 300°C fiber optical data communications link. Successful applicants will be given the opportunity to work with Sandia National Laboratory, to assure that the technology will complement ongoing research.

Questions – Contact Susan Rogers ([susan.rogers@ee.doe.gov](mailto:susan.rogers@ee.doe.gov))

***c. Advanced Power Electronics for Improved Illumination***—Numerous applications for efficient, advanced power electronics exist today in lighting applications, including fluorescent, discharge, and solid-state lighting. As described in the following paragraphs, grant applications are sought to: (1) develop new ballast designs to reduce component counts and add functionality for fluorescent lamps; (2) integrate power electronics into high intensity discharge lamps; and (3) develop advanced power electronics for solid state lighting.

(1) Contemporary ballast designs for fluorescent lamps have not fully exploited the promise of increased efficiency attributed to the use of advanced SiC power electronics. These new devices offer the opportunity to provide new functionality, and the replacement of some or all components with SiC components may ultimately result in new ballasts of significantly increased efficiency. Generally, high power SiC electronics are more costly than the conventional devices they replace. However, by developing common ballast power modules the component counts between product lines could be reduced, and the final product costs could remain competitive with conventional electronic ballasts. Therefore, grant applications are sought to develop common integrated circuits, power supplies or high side drivers for fluorescent lamp ballasts. Of particular interest are grant applications that also propose advanced ballast features (e.g., new functionality such as integrated controls for networking, dimming, occupancy sensing, or diagnostics; programmed controlled start; lumen driven current



## FY 2006 Topics

controls to minimize output variations at the end of lamp life, continuous power factor correction; and automatic adaptation to differing lamp types and currents) in addition to reduced component counts.

(2) Important to DOE's energy conservation mission is the prospect of using low power, high intensity discharge (HID) lamps in important markets such as retail sales or residential housing. These HID lamps, such as metal halides (MH) or high-pressure sodium (HPS) in lamp power ranges from 20 to 600 Watts, are more energy efficient and life-cycle-cost competitive than the conventional lamps they might replace. However, the magnetic ballasts used in conventional lamps possess limited functionality, inadequate for the flexible service that will be demanded in the key identified markets. Therefore, grant applications are sought to integrate efficient, advanced power electronics in HID lamps to provide new service features such as programmed controlled start, dimming (even within a limited range), networking, lumen maintenance and diagnostic interfaces. Performance goals for the new HID power supplies include: lamp power less than 70 watts; ballast efficiency greater than 95%; lamp power output greater than 80% at less than 1 second (3 second cold start); and 40% dimming.

(3) Commercially available power supplies for solid-state lighting (SSL) are derived from commercial-off-the-shelf (COTS) products that are not optimized for the SSL devices, applications, or controls. Therefore, for the SSL to perform efficiently, conserve energy, and provide needed functionality, especially in buildings, advanced power electronics and controls will be needed. Grant applications are sought to develop advanced power electronics for SSL that not only will extend the range of performance achieved with COTS products but will also be cost competitive with these products. Since SSL devices operate at drive voltages and currents significantly different than conventional sources, one area of interest is the development of novel ways to sense occupancy or determine task-specific illumination needs, which could reduce lighting loads for energy conservation or during periods of peak demand. Another area of interest is the use of advanced power electronics concepts to produce efficient SSL systems that operate entirely off the power grid. Grant applications must be applied to a specific SSL lighting system, so that a comparison to a conventional design can be made to calculate the potential energy conservation.

Questions – Contact James Brodrick ([james.brodrick@hq.doe.gov](mailto:james.brodrick@hq.doe.gov))

**d. Sensors and Controls**—In recent years, electronic sensors and controls have advanced in a number of fields. These solutions now could be applied to the control of systems and appliances in both commercial and residential buildings to increase energy efficiency and conservation in such applications as water heaters, furnaces, lighting, HVAC, and water systems, to mention a few. The advances in sensors and systems allow for the possibility of building controls systems that are capable self-learning, adaptive controls, fuzzy logic, or other advanced techniques. Grant applications are sought to develop: (1) master controls to optimize energy use in commercial buildings, (2) wireless sensor suites to minimize the cost of retrofitting buildings, and (3) control systems for under-floor air distribution for as-needed climate comfort.

(1) Grant applications are sought to develop master controls for integrating and optimizing energy usage (i.e., increase energy efficiency and reduce peak demand) of commercial building systems, sub-systems, and components (including HVAC, lighting, and daylighting systems). The master control should not only automate and communicate energy management capabilities, it also should be capable of communicating with the Internet and the local utility, in order to make energy management decisions based on grid conditions/prices and weather conditions. Of particular interest would be the provision of expansion capabilities to allow for the future integration of such things as on-site power generation or new building systems. In order to validate operational capabilities and demonstrate functional viability, the development effort should include basic tests on the master controller linked to a virtual building,

### FY 2006 Topics

(2) One of the major expenses associated with control system upgrades in existing buildings is the major effort required to wire the new system. Therefore, grant applications are sought to develop a wireless sensor suite that can reduce the cost of retrofitting existing commercial buildings with new control systems. The new suite of sensors should be cost effective, reliable, low maintenance, easy to install, and utilize plug-and-play capabilities. At a minimum, the sensors should work with existing technologies and components and include measurement capabilities for temperature, light, humidity, occupancy, pressure (air and liquid), and air velocity. The development effort should include tests under actual building conditions to verify sensor performance and communication capabilities.

(3) Under Floor Air Distribution (UFAD) systems have been, and are being, tested to maximize operating efficiency. However, one of the real values of a UFAD system appears to be the ability to stratify the indoor air, in order to provide comfort levels only where needed (and, by implication, reduce energy use by allowing climate conditions to extend beyond the human comfort zone in areas not physically occupied). Grant applications are sought to develop control systems for UFAS HVAC, which will take advantage of this potential.

Questions – Contact James Brodrick ([james.brodrick@hq.doe.gov](mailto:james.brodrick@hq.doe.gov))

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### 33. ENERGY EFFICIENT MEMBRANES

Separation technologies recover, isolate, and purify products in virtually every industrial process. Pervasive throughout industrial operations, conventional separation processes are energy intensive and costly. Separation processes represent 40 to 70 percent of both capital and operating costs in industry. They also account for 45 percent of all the process energy used by the chemical and petroleum refining industries every year. Industrial efforts to increase cost-competitiveness, boost energy efficiency, increase productivity, and prevent pollution demand more efficient separation processes. In response to these needs, the Department of Energy supports the development of high-risk, innovative separation technologies. In particular, membrane technology offers a viable alternative to conventional energy intensive separations.

## FY 2006 Topics

Successful membrane applications today include producing oxygen-enriched air for combustion, recovering and recycling hot wastewater, volatile organic carbon recovery, and hydrogen purification. Membranes have also been combined with conventional techniques such as distillation to deliver improved product purity at a reduced cost. Membrane separations promise to yield substantial economic, energy, and environmental benefits leading to enhanced competitiveness by reducing annual energy consumption, increasing capital productivity, and reducing waste streams and pollution abatement costs.

Despite the successes and advancements, many challenges must be overcome before membrane technology becomes more widely adapted. Technical barriers include fouling, instability, low flux, low separation factors, and poor durability. Advancements are needed that will lead to new generations of organic, inorganic, and ceramic membranes. These membranes require greater thermal and chemical stability, greater reliability, improved fouling and corrosion resistance, and higher selectivity. The objective is better performance in existing industrial applications, as well as opportunities for new applications. To advance the use of membrane separations, research is needed to develop new, more effective membrane materials and innovative ways to incorporate membranes in industrial processes. Grant applications must address the potential public benefits that the proposed technology would provide, both from reduced energy consumption and from the reduction in one or more of the following: materials consumption, water consumption, and toxic and pollutants dispersion. Grant applications should also include a plan for introducing the new technology into the manufacturing sector, in order to access capabilities for widespread technology dissemination. **Grant applications are sought only in the following subtopics:**

**a. Membrane Materials with Improved Properties**—Grant applications are sought to develop lower cost inorganic, organic, composite, and ceramic membrane materials in order to improve one or more of the following properties: (1) increased surface area per unit volume, (2) higher temperature operation (e.g., by using ceramic or metal membrane materials), and (3) suitability for separating hydrophilic compounds in dilute aqueous streams. Particular membrane materials of interest include nano-composites, mixed organic/inorganic composites, and chemically inert materials. Particular processes/systems of interest include membranes for the separation of biobased products, membranes for hydrogen separation and purification, and membranes for industrial applications.

For industrial applications, high temperature separations of hydrocarbons and other mixtures are of particular interest. For example, low molecular weight hydrocarbons are separated from natural gas by condensing them as a liquid, and the liquid is distilled to fractionate it, or the liquid is hydrocracked to olefins. However, chilling the natural gas in order to recover the condensable portion and then reheating it is inefficient, because the energy used to chill it cannot be recovered. Membranes, either as stand alone systems or hybridized with other separation technologies, may provide an energy efficient means of separating mixtures at the high temperatures at which these industrial processes are carried out.

For all membrane processes/systems, grant applications must be targeted toward the development of specific membrane materials for carefully defined commercial applications; efforts focused on generalized membrane material research are not of interest and will be declined. In order to assure the rapid commercialization of the technology, especially for use by U.S. manufacturers, applicants are strongly encouraged to engage in partnerships, so that the costs of the technology development and commercialization can be shared among manufacturers, suppliers, and end users.

Questions – Contact Charles Russomanno ([charles.russomanno@hq.doe.gov](mailto:charles.russomanno@hq.doe.gov))

**b. Membranes for Separations of Biobased Products**—Grant applications are sought to develop membrane technology to enhance the production of large volume, value-added chemical products using biomass feedstocks. These processes may use either enzymatic or chemical catalysis, and may be conducted in either

## FY 2006 Topics

aqueous reaction media or organic solvents. Grant applications must demonstrate a clear connection to a crop-based feedstock and a large volume chemical product (one that would be manufactured at greater than 500 million pounds). Of particular interest are (1) novel membrane processes that use reactive separation technology, which combines the reactive transformation with the separation; and (2) novel membrane materials with higher flux or selectivity, and with improved chemical and thermal membrane stability. Again, applicants are strongly encouraged to form partnerships involving manufacturers, suppliers, and end users, in order to promote and ensure the rapid development and commercialization of the technology in the U.S.

Questions – Contact Charles Russomanno ([charles.russomanno@hq.doe.gov](mailto:charles.russomanno@hq.doe.gov))

**c. Hydrogen Production**—Hydrogen can be produced from coal, natural gas, biomass, and biomass derivatives through the use of gasification, pyrolysis, reforming, and shift technologies. In all of these processes, the initial product is a hydrogen-rich producer gas or syngas, from which the hydrogen must be separated and purified. The most common approach today involves the use of pressure swing adsorption (PSA) technology. The use of membranes holds the promise of reducing costs by combining the separation and purification with the shift reaction in a reactive separation operation. Therefore, grant applications are sought to develop improved hydrogen membrane separation and purification technology for use in the production of hydrogen; the focus of the research should be on low cost, high flux rate, durable membrane systems that can be integrated with the shift reaction. Membranes of interest include ceramic ionic transport membranes, micro-porous membranes, and palladium based membranes. Such membranes could be used for a wide range of production capacities, from large central production facilities (50,000-300,000 kgs/day of hydrogen) to small-distributed production units (50-1000 kgs/day of hydrogen). Grant applications must include a careful analysis of the overall hydrogen separation efficiency, to assure that the proposed membrane separation will maximize the hydrogen recovered by the proposed process. Technology partnerships with manufacturers, suppliers, and especially end users are encouraged, in order to assure rapid commercialization of the technology in the U.S.

Questions – Contact Charles Russomanno ([charles.russomanno@hq.doe.gov](mailto:charles.russomanno@hq.doe.gov))

**d. Industrial Membrane Process Systems**—Grant applications are sought to enhance the separation capabilities of membranes used in industrial process streams. Proposed research should be aimed at developing and commercializing innovative membrane systems, using new or currently existing membranes, that can be robust when integrated within real-world processes (e.g., inert gas removal, isomer separation, aromatic/non-aromatic separations, sulfur removal, and removal of trace metals). Grant applications should seek to address one or more of the following needs: (1) techniques for overcoming scale-up problems related to contaminants in industrial streams (fouling, oil misting, etc.), (2) manufacturing technologies that would reduce the cost of membrane modules, (3) anti-fouling and anti-flux schemes to improve the long-term operability of membrane systems, and (4) methods to regenerate membrane performance and lower membrane maintenance costs. Also of interest is the integration of membranes with other technologies (such as the integration of membranes with distillation systems, or with adsorption or extraction processes), in order to address specific process issues. For all grant applications, the overriding goal is to enhance U.S. industrial process efficiency to the maximum possible extent by increasing the separation process efficiency. Therefore, priority will be given to applications that carefully examine the efficiency of the proposed membrane technology within the targeted application. Grant applications should also include a process evaluation and an economic analysis along with the R&D effort. Lastly, technology partnerships involving U.S. manufacturers, suppliers, and end users are strongly encouraged.

Questions – Contact Charles Russomanno ([charles.russomanno@hq.doe.gov](mailto:charles.russomanno@hq.doe.gov))



## FY 2006 Topics

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**FY 2006 Topics**  
**PROGRAM AREA OVERVIEW**  
**OFFICE OF FUSION ENERGY SCIENCES**

The Department of Energy sponsors fusion science and technology research as a valuable investment in the clean energy future of this country and the world, as well as to sustain a field of scientific research - plasma physics - that is important in its own right and has produced insights and techniques applicable in other fields of science and industry. The mission of the Fusion Energy Sciences (FES) program is to acquire the knowledge base needed for an economically and environmentally attractive fusion energy source. FES research efforts seek to: (1) understand the physics of plasmas, the fourth state of matter – plasmas constitute most of the visible universe, both stellar and interstellar, and progress in plasma physics has been the prime engine driving progress in fusion research; (2) identify and explore innovative and cost-effective development paths to fusion energy – the current fusion program encourages research on a wide range of approaches including the Tokamak (the leading power plant candidate), other magnetic configurations, and inertial fusion energy using particle beams or lasers; and (3) explore the science and technology of energy producing plasmas, the next frontier in fusion research, as a partner in a international effort – reducing costs, avoiding duplication of efforts, and bringing the best available scientific and engineering talent together to seek solutions to complex problems can best be done through the cooperative efforts of the world fusion community.

This is a time of important progress and discovery in fusion research. The U.S. has joined the international consortium to fabricate and operate the International Thermonuclear Experimental Reactor (ITER), which is to demonstrate burning plasma. The FES program is making great progress in understanding turbulent losses of particles and energy across magnetic field lines used to confine fusion fuels, identifying and exploring innovative approaches to fusion power that may lead to more economical power plants, and encouraging private sector interests to apply concepts developed in the fusion research program. It is felt that small businesses, by performing research within the following technical topics, can make significant contributions to these efforts. The following topics are restricted to science and technology relevant to magnetically confined plasmas and inertial fusion energy. Grant applications pertaining to fusion energy concepts not based specifically on the use of plasmas for producing energy/electricity for non-defense purposes will be declined.

For additional information regarding the Office of Fusion Energy Sciences priorities, [click here](#).

### **34. ADVANCED TECHNOLOGIES AND MATERIALS FOR FUSION ENERGY SYSTEMS**

An attractive fusion energy source will require the development of superconducting magnets and materials as well as technologies that can withstand the high levels of surface heat flux and neutron wall loads expected for the in-vessel components of future fusion energy systems. These technologies and materials will need to be substantially advanced relative to today's capabilities in order to achieve safe, reliable, economic, and environmentally-benign operation of fusion energy systems. A list of items under the heading “Goods and Services that are needed by the Fusion laboratories” can be found at [www.ofes.fusion.doe.gov](http://www.ofes.fusion.doe.gov) . **Grant applications are sought only in the following subtopics:**

**a. Plasma Facing Components**—The plasma facing components (PFCs) in energy producing fusion devices will experience 5-15 MW/m<sup>2</sup> under normal operation (steady-state) and off-normal energy deposition up to 1 MJ/m<sup>2</sup> within 0.1 to 1.0 ms. Refractory solid surfaces represent one PFC option. These PFCs are envisioned to have a refractory metal heat sink, cooled by helium gas, and a plasma facing surface, consisting of an engineered refractory metal surface or a thin coating of refractory material that minimizes thermal stresses. The materials being considered include tungsten and molybdenum. Grant applications are sought to develop: (1) innovative refractory alloys having good thermal conductivity (similar to Mo, at a minimum), resistance to recrystallization and grain growth, good mechanical properties (e.g., strength and ductility), and resistance to

### FY 2006 Topics

thermal fatigue; (2) innovative refractory metal heat sink designs for helium gas cooling; (3) efficient fabrication methods for engineered surfaces that mitigate the stresses due to high heat flux; and (4) joining or coating methods, for attaching the plasma facing material to the heat sink, that are reliable, efficient to manufacture, and capable of high heat transfer.

In addition, grant applications are sought to develop new or improved techniques for the non-destructive evaluation (NDE) of the joint between the PFC armor and the heat sink, for PFCs containing round cooling channels and complex three-dimensional curvature. Of particular interest is the joint quality between beryllium and copper alloys, between copper and stainless steel, and between refractory armor and refractory heat sinks. Examples of existing NDE techniques include ultrasonic evaluation, neutron radiography, and hot water thermography. Approaches of interest include the development of improvements to these techniques or the development of entirely new techniques. The objective is to ascertain the quality of the armor/heat sink joint during the PFC manufacturing process.

Another option is to use a flowing liquid metal surface as a plasma facing component, an approach which will require the production and control of thin, fast flowing, renewable films of liquid lithium, gallium, or tin for particle control at divertors. Grant applications are sought to develop: (1) techniques for the production, control, and removal of flowing (velocity 0.01 to 10 m/s) liquid metal films (0.5-5 mm thick) over a temperature controlled substrate; (2) advances in materials that are wet by liquid metals at temperatures near the respective metal melting point and that produce uniform, well-adhered films; (3) techniques for active control of liquid metal flow and stabilization in the presence of plasma instabilities (time and space varying magnetic field); (4) computational tools that model the flow and magnetohydrodynamic response of flowing liquid metals; and (5) cost-effective experimental techniques that integrate items (1) to (4) above to allow advanced plasma-material-interaction testing and simulation.

Questions – Contact Gene Nardella ([gene.nardella@science.doe.gov](mailto:gene.nardella@science.doe.gov))

**b. Blanket Materials**—The pebble-bed solid breeder configuration introduces several operational limits: thermo-mechanical uncertainties caused by pebble bed wall interaction, potential sintering and subsequent macro-cracking, and a low pebble bed thermal conductivity – all of which result in small characteristic bed dimensions and limit windows of operation. A new form of solid breeder morphology is required that holds the promise for increased breeding ratios, dictated by increased breeder material density; long term structural reliability; and enhanced operational control, compared to packed beds. Grant applications are sought for new solid breeder material concepts that include: (1) increased breeder material densities (>80%); (2) higher thermal conductivities (provided by a fully interconnected structure, as opposed to point contacts between pebbles); (3) bonded contacts to cooling structures (instead of point contacts between pebbles and wall); (4) the absence of major geometry changes between beginning-of-life and end-of life (such as sintering in pebble beds) in the presence of high neutron fluence; and (5) structural integrity in freestanding and self-supporting structures with significant thermo-mechanical flexibility.

Flow channel inserts (FCIs) act as magnetohydrodynamic and thermal insulators in ferritic steel channels containing, for example, a slowly flowing tritium breeder such as molten Pb-17Li alloy. The insert geometry is approximately C-shaped in straight channels, with more complex shapes possible for insertion in manifolds and other complex-geometry elements in the flow path. Although SiC/SiC composite is a candidate FCI material, its use would differ from its potential application as a structural material in that high thermal and electrical conductivity would not be desirable. In fact, the electrical conductivity should be as low as possible, with a target range from 1 to  $10 \Omega^{-1} \text{m}^{-1}$ . In addition, the strength requirements for a SiC/SiC FCI are reduced compared to the composite's application as a structural material, because the primary stresses and pressure loads will be very low. On the other hand, the insert must be able to withstand thermal stresses from temperature gradients in the range of 10-40 C/mm. Grant applications are sought to develop manufacturing

## FY 2006 Topics

techniques for radiation resistant, low thermal/electrical conductivity SiC/SiC composites that would prevent the Pb-17Li alloy from penetrating any porosity in the matrix. One approach that has been envisioned is the use of a final “sealing” layer of SiC matrix material, which would be near theoretical density and cover any porosity or exposed fibers in the main body of the insert. Two-dimensional weaves are also thought to be satisfactory, as well as an effective way to reduce electrical conductivity normal to the interface between the insert and the Pb-17Li (the more important of the directions). In addition, grant applications are sought to develop experimental techniques for determining: (1) the compatibility between the SiC/SiC composite and such breeder materials as Pb-17Li alloy, and (2) the insert integrity under cyclic thermal loading.

One of the missions of the International Thermonuclear Experimental Reactor (ITER) project is the integrated testing of fusion blanket modules in a true integrated fusion environment. This ITER fusion environment includes radiation and magnetic fields, along with surface and volumetric heating, under pulsed and/or steady-state plasma operation. The “test blanket modules” (TBMs) will be complicated systems of different functional materials (breeder, multiplier, coolant, structure, insulator, etc.) in various configurations with many responses and interacting phenomena (e.g., thermomechanical, thermofluid, nuclear). As part of the design and validation process an overall simulation of a “virtual” TBM integrating all of the individual computational modeling simulations at the system level is essential to define meaningful experiments. Such a project would be inherently multi-scale and multi-physics and will require careful code and algorithm design. Therefore, grant applications are sought to develop a TBM simulation code that can provide visual animations of: (1) fluid flow and thermal hydraulic characteristics; (2) the thermal response of all materials (structure, breeder, multiplier, coolant, insulator, etc.); (3) structural responses such as stress and deformation magnitudes with respect to different loadings, including both steady-state surface heat flux and dynamic loadings; and (4) other important performance characteristics of the TBM. The overall code framework/structure must effectively link all of the simulation components of the virtual TBM and serve as an efficient, useful, and user-friendly tool.

Questions – Contact Warren Marton ([warren.marton@science.doe.gov](mailto:warren.marton@science.doe.gov))

**c. Superconducting Magnets and Materials**—New or advanced superconducting magnet concepts are needed for plasma fusion confinement systems; i.e., high field magnets (12 to 20 T) and low loss pulsed magnets. Grant applications are sought for: (1) innovative and advanced materials and manufacturing processes that have a high potential for improved conductor performance and low fabrication costs; (2) cryogenic superconductor materials with high critical current density, low sensitivity to strain degradation effects, and radiation resistance; (3) novel, low-cost cable designs and fabrication techniques, which minimize conductor strain; (4) superconducting joints for high field and pulsed applications; (5) novel, advanced sensors and instrumentation for non-invasively monitoring magnet and helium parameters (e.g., pressure, temperature, voltage, mass flow, quench, etc.); (6) thick (15-30 cm), weldable, structural case materials with high strength and toughness at 4 K; (7) welding techniques for such thick cryogenic structural materials; and (8) radiation-resistant electrical insulators (e.g., wrapable inorganic insulators and low viscosity organic insulators, which exhibit low out gassing under irradiation).

Questions – Contact Gene Nardella ([gene.nardella@science.doe.gov](mailto:gene.nardella@science.doe.gov))

**d. Structural Materials and Coatings**—Grant applications are sought for research that will enable the development of advanced reduced-activation materials and electrically insulating coatings. Materials systems of interest are limited to: (1) oxide dispersion strengthened (ODS) ferritic steels; (2) high-toughness tungsten alloys; and (3) electrically insulating coatings on vanadium (V) or ferritic/martensitic steel to reduce magnetohydrodynamic (MHD) effects in liquid metal cooled systems. Grant applications are also sought for the development of: (4) advanced joining methods and/or rapid prototyping methods for the fabrication of intricate structures containing thin-walled (~1 to 3 mm) coolant channels – of particular interest is the development of practical methods for fabricating ferritic/martensitic mockup blanket modules, which do not

## FY 2006 Topics

degrade the properties of the material; and (5) innovative modeling tools, which range from atomistic and molecular dynamics simulations of atomic collision and defect migration events (including solute binding effects) to improved finite element analysis (mechanical deformation and fracture) or thermodynamic stability (materials by design) tools.

For ODS ferritic steels, approaches of interest include the development of low cost production techniques, improved isotropy of mechanical properties, development of joining methods that maintain the properties of the ODS steel, and development of improved ODS steels with the capability of operating up to ~800°C, while maintaining adequate fracture toughness at room temperature and above. For tungsten alloys, areas of interest include improvements in the grain boundary strength and fracture toughness, and joining techniques. For electrical insulating coatings, grant applications must: (1) account for compatibility with both the coated structural alloy and liquid metal coolant for long time operation at 400-700°C (grant applications must be limited to vanadium-Lithium (V-Li) and ferritic steel-lead lithium (PbLi) systems); (2) address the use of candidate coatings on actual system components; and (3) account for the long term reliability and/or *in situ* repair of defects that could develop in the coating. For all of these materials systems, priority will be given to innovative methods or experimental apparatuses that enhance the ability to obtain key mechanical or physical property data on miniaturized specimens, and to the micromechanics evaluation of deformation and fracture processes.

Questions – Contact Gene Nardella ([gene.nardella@science.doe.gov](mailto:gene.nardella@science.doe.gov))

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## 35. FUSION SCIENCE AND TECHNOLOGY

The Fusion Energy Sciences program currently supports several fusion experiments with many common objectives. These include expanding the scientific understanding of plasma behavior and improving the performance of high temperature plasma for eventual energy production. The goals of this topic are to develop and demonstrate innovative techniques, instrumentation, and concepts for measuring magnetic plasma parameters; for plasma processing; for magnetic plasma simulation, control, and data analysis; and for innovative approaches to fusion. It is also intended that concepts developed as part of the fusion research program will have application to industries in the private sector. A list of items under the heading “Goods and Services that are needed by the Fusion laboratories” can be found in the Office of Fusion Energy Sciences (OFES) Website (URL: [WWW.OFES.FUSION.DOE.GOV](http://WWW.OFES.FUSION.DOE.GOV)). **Grant applications are sought only in the following subtopics:**

**a. Diagnostics for Magnetic and Inertial Fusion Plasma Research**—Grant applications are sought to develop: (1) measurement techniques for parameters such as plasma density, electron and ion temperature, plasma current and current density, plasma position and shape, impurity density, magnetic field strength, ambipolar potentials, and radiation from the plasma; (2) new diagnostics for measurements in the three-dimensional plasmas characteristic of stellarators, as well as diagnostics especially adapted to other innovative concept experiments; (3) diagnostic methods for examining the edge and divertor regions in tokamak plasmas, and for understanding electron thermal transport (high-k fluctuation diagnostics, core magnetic fluctuation diagnostics, and profile diagnostics on smaller devices); and (4) diagnostics applicable to the management of particle and energy inventory, to profile control and thermal barrier formation, and to burning plasmas including ITER (International Thermonuclear Experimental Reactor). Approaches of interest include new techniques and methods to improve the accuracy and resolution of existing diagnostics (e.g., improving the signal-to-noise ratio or extending the range of measured parameters), visualization of turbulence in two and three dimensions, and imaging of non-thermal electrons in two dimensions. Measurements must be both spatially and temporally resolved for both the absolute values of parameters and for small relative differences. Real-time measurements of the pertinent parameters will be required for providing feedback and plasma control. Further information on experiments on innovative fusion concepts is available at the OFES Website.

Grant applications are also sought to develop sets of miniature (non-perturbing) magnetic probes and associated circuitry as an integrated package, suitable for detecting the magnetic oscillations often associated with changes in plasma transport properties. The ranges of interest for the frequency and amplitude of these magnetic fluctuations are 10 kHz to 100 MHz and 0.01 to 100 G, respectively, as shown by research on fusion plasma experiments. Approaches of interest must account for the complex mode structure of these fluctuations – i.e., fluctuation amplitudes and phases differ markedly with spatial position. In addition, the probes should be moveable, ultra-high-vacuum compatible, and able to withstand exposure to conditions expected in the edge of fusion research devices.

## FY 2006 Topics

Grant applications are also sought to apply diagnostics technology, developed for fusion energy, to the use of plasmas in manufacturing. These grant applications should show how the application of these diagnostics would contribute to the understanding of plasmas used in manufacturing, as well as provide an improved basis for modeling these plasmas.

Lastly, grant applications are also sought to develop instrumentation and time-resolved measurement techniques of high-charge-density heavy-ion beams of energy greater than 0.5 MeV and radius  $\sim 1$  to 5 cm. Beam parameters of interest include current, density distribution, beam position, energy, energy distribution, emittance, and space potential in the injector, transport, and final focus sections. Of particular interest are innovative non-intercepting position detectors and optical (including scintillator-based) beam diagnostics suitable for rapid characterization of beams in both the present (0.5 to 2 MeV) and higher energy ranges, and diagnostics for characterizing trapped secondary electron distributions. Further information may be obtained in the HIF Symposia series (see reference for 12th International Symposium).

Questions – Contact Charles Finfgeld ([charles.finfgeld@science.doe.gov](mailto:charles.finfgeld@science.doe.gov))

**b. Components for Heating and Fueling of Fusion Plasmas and Tokamak Facility Operations**—Grant applications are sought to develop components related to the generation, transmission, and launching of high power electromagnetic waves in the frequency ranges of ion cyclotron resonance heating (50 to 300 MHz), lower hybrid resonance heating (2 to 20 GHz), and electron cyclotron resonance heating (100 to 300 GHz). Components of interests include power supplies, fault protection devices, antenna and launching systems, tuning and matching systems, unidirectional couplers, circulators, mode convertors, windows, output couplers, loads, energy extraction systems from spent electron beams and particle accelerators, and diagnostics to evaluate the performance of these components.

Grant applications are also sought to (1) develop computer codes for the simulation of maintainability/reliability assurance technologies and for plant operations, applicable to fusion experiments; and (2) apply artificial intelligence to the monitoring of tokamak plant operation and real-time or impending fault condition.

Questions – Contact T.V. George ([tv.george@science.doe.gov](mailto:tv.george@science.doe.gov))

**c. Plasma Simulation and Data Analysis**—The simulation of fusion plasmas is important to the development of plasma discharge feedback and control techniques. The simulations can be used to make reliable predictions of the performance of proposed feedback and control schemes and to identify those that should be tested experimentally. Unfortunately, accurate simulations of fusion plasmas are very difficult because of the enormous range of temporal and spatial scales involved in plasma behavior. Considerable progress has been made in recent years in understanding and simulating plasma turbulence, along with associated transport, macroscopic equilibrium and stability, and the behavior of the edge plasma. However, there remains a need to integrate the various plasma models. Grant applications are sought to develop computer algorithms applicable to plasma simulations that account for an expanded number of plasma features and an integration of plasma models. Examples of possible approaches include algorithms that incorporate mathematical techniques such as neural networks, sparse linear solvers, and adaptive meshes; algorithms for coupling disparate time and space scales; efficient methods for facilitating comparison of simulation results with experimental data; and visualization tools for local and remote analysis, and presentation of multi-dimensional time dependent data.

Grant applications are also sought to develop software tools useful for the analysis and distribution of fusion data. Areas of interest include methods for coupling codes across architectures and through the Internet; techniques for making highly configurable scientific codes; data management and analysis techniques for large data sets; and remote collaboration tools that enhance the ability of a geographically distributed group of scientists to interact in real-time.

## FY 2006 Topics

The computer algorithms and programming tools should be developed using modern software techniques and should be based on the best available models of plasma behavior.

Questions – Contact Rostom Dagazian ([rostom.dagazian@science.doe.gov](mailto:rostom.dagazian@science.doe.gov))

**d. Components and Modeling Support for Innovative Approaches to Fusion—**Innovative Confinement Concepts is a broad-based, long-range, research activity that specifically addresses parameters that could lead to the attractive and practical use of fusion power. This research includes investigations in stellarators, spherical torus, reversed field pinches, field reversed configurations (FRC), spheromaks, magnetized target fusion, levitated dipole, flow-stabilized (long-pulse) z-pinch, rotationally stabilized magnetic mirror, inertial electrostatic confinement, and magneto-Bernoulli confinement. Grant applications are sought for scientific and engineering developments, including computational modeling, in support of any aspect of these research activities. Of particular interest are grant applications that explore the feasibility of plasma acceleration and injection into magnetic fields and/or magnetized plasmas, generation of plasma rotation, and disruption mitigation. Further information on experiments on innovative fusion concepts is available at the OFES Website.

Questions – Contact Francis Thio ([francis.thio@science.doe.gov](mailto:francis.thio@science.doe.gov))

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## FY 2006 Topics

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## 36. HIGH ENERGY DENSITY PHYSICS FOR INERTIAL FUSION ENERGY

Inertial fusion seeks to produce fusion reactions by creating plasmas of extremely high density and using inertia to contain momentarily the extreme pressure generated by the fusion burning plasma. In order for inertial fusion to achieve significant energy production, it will be necessary to develop attractive physics pathways for providing the necessary conditions for ignition and burn. In turn, these conditions will require states of matter with extremely high energy density (HED). For this purpose, HED states are defined as states of matter with energy densities exceeding about  $10^{11}$  J/m<sup>3</sup> and temperature exceeding 1 eV. However, the physics of matter at such high energy densities is not well established – it is an emerging field that cuts across many areas of science. Therefore, the Office of Fusion Energy Sciences (OFES) sponsors research in heavy ion beams to produce these HED states, along with studies of the physics of fast ignition and high-temperature dense magnetized plasmas. This topic seeks to supplement the on-going research activities as well as to develop new techniques for creating or studying HED states relevant to the pursuit of inertial fusion energy. A list of items under the heading "Goods and Services that are needed by the Fusion laboratories" can be found in the Office of Fusion Energy Sciences Website (URL: [WWW.OFES.FUSION.DOE.GOV](http://WWW.OFES.FUSION.DOE.GOV)). **Grant applications are sought only in the following subtopics:**

**a. Beam Generation, Compression, and Focusing**—In current OFES programs, ion beams are produced by induction linear accelerators with components to produce, accelerate, transport, and focus beams of required energy and intensity. Over the next few years, the research will concentrate on developing intense ion sources and on studying the physics of spatial compression, neutralized transport, and focusing of the beam. The research is led by the Virtual National Laboratory for Heavy Ion Fusion, a collaboration among Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, and the Princeton Plasma Physics Laboratory. Grant applications are sought to support the development of high current, high brightness ion sources for heavy ion induction linacs. Grant applications are also sought for research in the spatial compression and focusing of high-current, high brightness ion beams. Research of interest includes theoretical, computational, and/or experimental investigations.

Questions – Contact Francis Thio ([francis.thio@science.doe.gov](mailto:francis.thio@science.doe.gov))

**b. Fast Ignition**—The Fast Ignition concept employs two drivers to create inertial fusion: one for compression, and one for the ignition of a small portion of the compressed fuel. The main requirement and challenge for Fast Ignition is to deliver the ignition energy to the compressed fuel. In the most common approach, petawatt laser energy is nominally deposited in the coronal plasma surrounding the compressed fuel, resulting in a relativistic electron beam. Ignition depends on the successful propagation of that electron beam to the fuel and the effective heating of a small portion of that fuel. In this approach, the energy transport by relativistic electrons to

## FY 2006 Topics

the high-density fuel to achieve ignition is a key physics issue. An alternative approach, in which energetic proton beams are used as igniter beams, also is under consideration. These Fast Ignition concepts are being funded by the OFES at the University of Rochester, Lawrence Livermore National Laboratory, General Atomics, Ohio State University, University of Texas at Austin, and the University of Nevada at Reno. Grant applications are sought for computational, experimental, and component development in support of these ongoing Fast Ignition research efforts at these institutions. Grant applications that address the development of petawatt lasers are outside the scope of this solicitation and will be declined.

Questions – Contact Francis Thio ([francis.thio@science.doe.gov](mailto:francis.thio@science.doe.gov))

**c. Innovative Approaches for Creating and/or Studying States of High Energy Density**—Grant applications are sought to develop innovative approaches for creating and/or understanding HED states. Areas of interest include, but are not limited to: (1) transport of thermal energy, kinetic energy, momentum and particles in these states, especially the effects of externally applied or self-generated magnetic fields on the transport processes; (2) and theoretical, computational, and/or experimental investigations for creating and/or using dense, high Mach-number, high velocity plasma jets/beams to create HED states. However, grant applications that address the development of petawatt lasers are outside the scope of this solicitation and will be declined.

Questions – Contact Francis Thio ([francis.thio@science.doe.gov](mailto:francis.thio@science.doe.gov))

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## FY 2006 Topics

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## PROGRAM AREA OVERVIEW HIGH ENERGY PHYSICS

Through fundamental research, scientists have found that all physical matter is composed of apparently point-like particles, called leptons and quarks. These constituents of matter were created following the "big-bang" which originated our universe, and they are components of every object that exists today. We also understand a great deal about the four basic forces of nature: electromagnetism, the strong nuclear force, the weak nuclear force, and gravity. For example, in the past we have learned that the electromagnetic and weak forces are two components of a single force, called the electro-weak force. This unification of forces is analogous to the unification in the mid-nineteenth century of electric and magnetic forces into electromagnetism. History shows that, over a period of many years, the understanding of electromagnetism has led to many practical applications that form the technical basis of modern society.

The goal of the Department of Energy's (DOE) High Energy Physics (HEP) program is to provide mankind with new insights into the fundamental nature of energy and matter and the forces that control them. This program is a major component of the Department's fundamental research mission. Such fundamental research provides the necessary foundation that enables the nation to advance its scientific knowledge and technological capabilities, to advance its industrial competitiveness, and possibly to discover new and innovative approaches to its energy future.

## FY 2006 Topics

Experimental research in HEP is largely performed by university scientists using particle accelerators located at major laboratories in the U.S. and abroad. Under the HEP program, the Department operates the Fermi National Accelerator Laboratory (Fermilab) near Chicago, IL and the Stanford Linear Accelerator Center (SLAC) near San Francisco, CA. Furthermore, the Department has a significant role in the Large Hadron Collider project under construction at the CERN laboratory in Switzerland. The Tevatron at Fermilab is currently the world's highest energy accelerator. SLAC also provides unique experimental capabilities. While much progress has been made during the past five decades in our understanding of particle physics, future progress depends to a great degree on the availability of new state-of-the-art technology for accelerators, colliders, and detectors operating at the high energy and/or high intensity frontiers.

Within HEP, the High Energy Technology subprogram supports the research and development required to extend relevant areas of technology in order to support the operations of highly specialized accelerators, colliding beam facilities, and detector facilities which are essential to the goals of the overall HEP program. The DOE SBIR program provides a focused opportunity and mechanism for small businesses to contribute new ideas and new technologies to the pool of knowledge and technical capabilities required for continued progress in HEP research, and to turn these novel ideas and technologies into new business ventures.

For additional information regarding the Office of High Energy Physics priorities, [click here](#).

### 37. ACCELERATOR TECHNOLOGY FOR THE INTERNATIONAL LINEAR COLLIDER

The DOE High Energy Physics (HEP) program supports research and development for the International Linear Collider (ILC), a 500 GeV superconducting linear electron-positron collider that will probe the energy frontier with unprecedented precision [1-6]. Advanced R&D is needed in support of this project in: (a) 1.3 GHz superconducting radiofrequency (SRF) systems, (b) beam instrumentation and feedback systems, (c) magnet and fast kicker technology, and (d) polarized radiofrequency (RF) photocathode sources. Relevance to the ILC must be explicitly described. Grant applications that propose using resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

**a. Superconducting Radiofrequency Systems**—Research is needed in a variety of superconducting RF areas to support the development of the ILC. Accordingly, grant applications are sought:

(1) to develop high gradient, 1.3 GHz superconducting RF cavities, with application to the accelerating structures needed for the ILC. Multi-cell cavities, with gradients greater than 35 MV/m and  $Q$ -factors greater than  $5 \times 10^9$ , are of particular interest. Priority areas of research focus include new cavity geometries or materials, improved methods of cavity fabrication, advances in surface preparation and processing, improved control of field emission, and suppression of high-field  $Q$ -slope.

(2) for technology to support the development of fundamental power couplers and tuners for 1.3 GHz SRF cavities. Areas of interest include improvements to current coupler design (resulting in reduced conditioning time, reduced cost, and improved reliability), as well as new tuner designs and concepts.

(3) to develop high efficiency 1.3 GHz modulators and klystrons, capable of operation at peak power levels on the order of 10 MW, with a pulse width of 1-3 ms, at a repetition rate of 5-10 Hz. The modulator efficiency should be greater than 75%, and the klystron efficiency should be greater than 65%. Grant applications also are sought to develop power distribution systems suitable for the transport of L-band microwave power at the level of 10 MW (peak).

### FY 2006 Topics

(4) to develop digital, low-level RF systems to control the phase and amplitude of SRF cavities operating at 1.3 GHz, with loaded  $Q$ -values in the range of  $10^6$ . Of particular interest are systems capable of phase control at the level  $0.5^\circ$  or better, and amplitude control at the level of 0.1% or better.

(5) to develop SRF cavity processing technology to clean and improve the smoothness of the surface of niobium (Nb) cavities.

(6) for research and development leading to the design and fabrication of ILC cryomodules for 1.3 GHz superconducting cavity strings. Each ILC cryomodule contains several 1.3 GHz cavities and couplers in their He vessels, quadrupoles, tuners, as well as a 2K helium distribution system.

(7) to increase the technical refrigeration efficiency – from 20% Carnot to 30% Carnot – for large systems (e.g 10 kW at 2K), while maintaining higher efficiency over a capacity turndown of up to 50%. This might be done, for example, by reducing the number of compression stages or by improving the efficiency of stages. Grant applications also are sought to develop improved and highly efficient liquid helium distribution systems.

(8) to develop technologies to facilitate the installation, support, and alignment of very large accelerator beam line lattice elements.

Questions – contact LK Len ([lk.len@science.doe.gov](mailto:lk.len@science.doe.gov))

**b. Beam Instrumentation and Feedback Systems**—Instrumentation and feedback systems are needed to support the development of the ILC. Accordingly, grant applications are sought to develop:

(1) fast transverse feedback systems, appropriate for controlling vertical beam jitter at the 0.1 sigma level, in linear colliders with long bunch trains (on the order of 1 ms). Areas of particular interest include systems with bandwidth sufficient to control single bunches within a train (with a bunch separation of order 100 ns), and systems that can operate on a train-by-train basis (with a train repetition period of order 5 Hz). System design should be based on the bunch parameters of the ILC.\*

(2) linac beam position monitoring systems capable of single-bunch position resolution in the range of 1-10  $\mu\text{m}$  (rms). The system design must be relevant for the bunch parameters of the ILC.\*

(3) high resolution beam profile monitoring systems capable of measuring the emittance of a high energy electron/positron beam, with the bunch parameters of the ILC.\* The emittance should be measured with an accuracy of 10% or better.

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**c. Magnet and Fast Kicker Technology**—Advanced magnet and fast kicker technologies are needed to support the development of the ILC. Accordingly, grant applications are sought to develop:

(1) wiggler systems suitable for use in the damping rings of the ILC. Both permanent magnet and superconducting magnet systems are of interest. Over one damping time, the uniformity of the wiggler field must be sufficient to provide a dynamic aperture of approximately 10 sigma, as determined by tracking particles characteristic of the injected positron beam. The wiggler physical aperture must provide an acceptance of approximately 5 sigma.

(2) fast kicker systems useful for single bunch injection/extraction systems in the ILC damping rings. The rise and fall time of the field seen by the beam must be 20 ns or less, preferably closer to 3-4 ns. The overall system



## FY 2006 Topics

(possibly consisting of a number of kicker modules) should be capable of delivering a 0.6 mrad kick to a 5 GeV electron beam. The kicker should be capable of burst operation at 3 MHz for a duration of up to 1 ms, at a repetition rate of 5 Hz.

(3) short-period helical undulators, suitable for use with a high-energy ( $>150$  GeV) electron beam, to produce an intense 10 MeV photon beam. (The photons subsequently would be used to produce showers in a thin target, providing an undulator-based positron source for the ILC.) The undulator field, gap, and period must be consistent with the requirements of the ILC undulator-based source.\*[1]

(4) quadrupole focusing systems, capable of achieving the demagnification needed at the interaction point of the ILC, while satisfying the geometry constraints imposed by the beam crossing angle and the particle detectors. [2]

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**d. Polarized RF Photocathode Sources**—Grant applications are sought for the development of polarized electron sources which operate with RF guns, and consequently can provide very low emittance beams. The electron polarization must be greater than 80%, with an rms invariant emittance of  $4\pi$  mm-mrad or less. The bunch parameters and format should be those of the ILC.\*

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\* The ILC linac parameters include a beam intensity of  $2 \times 10^{10}$  electrons or positrons per bunch, in trains of about 3000 bunches, separated by about 300 ns. The trains themselves occur at a repetition rate of 5 Hz. Each bunch has an rms invariant transverse emittance of about  $8 \mu\text{m}$  (horizontal) by  $0.02 \mu\text{m}$  (vertical), with an rms bunch length of  $300 \mu\text{m}$ . Beam size at the IP is about 6 nm vertically. The energy varies from 5 GeV at the start of the linac, to 250 GeV at the end.

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### 38. ADVANCED CONCEPTS AND TECHNOLOGY FOR HIGH ENERGY ACCELERATORS

The DOE High Energy Physics (HEP) program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this program in the following areas: (1) new concepts for acceleration, (2) novel device and instrumentation development, (3) inexpensive electron sources, and (4) computer software for control systems and advanced accelerator modeling. Relevance to applications in HEP must be explicitly described in the submitted grant applications. Advanced accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 48. Grant applications that propose using resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. Grant applications are sought only in the following subtopics:

**a. New Concepts for Acceleration**—Grant applications are sought to develop new or improved acceleration concepts. Designs should provide very high gradient ( $>100$  MV/m for electrons or  $>10$  MV/m for protons) acceleration of intense bunches of particles, or efficient acceleration of intense ( $>50$  mA) low energy (of order  $<20$  MeV) proton beams. For all proposed concepts, stageability, beam stability, manufacturability, and high-wall plug-to-beam power efficiency should be considered.

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**b. Novel Device and Instrumentation Development**—Grant applications are sought for the development of electromagnetic, permanent magnet, or silicon microcircuit-based charged particle optical elements for particle beam focusing. Examples include, but are not limited to, dipoles, quadrupoles, higher order multipole correctors for use in electron linear accelerators, and solenoids for use in electron-beam or ion-beam sources or for klystron or other radio frequency amplifier tubes operating at wavelengths from 0.7 to 10 cm. In these optical elements, permanent magnets or hybrid magnets incorporating magnetic materials that have very high residual magnetization, radiation resistance, and thermal stability (low variation of field strength with temperature) are of particular interest. Also of interest are undulators for bunching high energy electron beams needed for phased injection in high frequency accelerating structures and for generating coherent transition radiation.

Grant applications are also sought for: (1) novel charged particle beam monitors to measure the transverse or longitudinal charge distribution, emittance, or phase-space distributions of small radius ( $0.1\text{ }\mu\text{m}$  to  $5\text{ mm}$  diameter), short length ( $10\text{ }\mu\text{m}$  to  $10\text{ mm}$ ) relativistic electron or ion beams; (2) devices capable of measuring and recording the Schottky or transition radiation spectrum of these beams (proposed techniques should be nondestructive, or minimally perturbative, to the beams monitored and have computer-compatible readouts); (3) lasers for laser-accelerator applications that provide substantial improvements over currently available lasers in one or more of the following parameters: (i) longer wavelengths (up to  $2$  to  $2.5\text{ }\mu\text{m}$  for use with Si transmissive optics), (ii) very short wavelengths ( $<200\text{ nm}$ ) with low mode numbers ( $M\text{-squared} < 100$ ) and high pulse energy ( $>0.1\text{ J}$ ) for photo-ionized plasma sources, (iii) higher power, (iv) higher repetition rates, (v) shorter pulse widths; and (4) achromatic, isochronous compact focusing systems with broad energy acceptance and compact broadband ( $10\text{-}100\text{ MeV}$ ) spectrometers, suitable for use in laser acceleration experiments.

Grant applications are sought to develop high density (range of  $10^{18}\text{-}10^{20}\text{ cm}^{-3}$ ), high repetition rate ( $\geq 10\text{ Hz}$ ) pulsed gas jets, capable of producing longitudinally tailored density profiles with long lengths (centimeter scale) and narrow widths (few hundred microns) for use in laser wakefield accelerators. The gas jet should have sharp entrance gradients, with a transition region/length on the order of  $500\text{ }\mu\text{m}$ . The pulse duration of the jets should be less than  $500\text{ }\mu\text{s}$  to minimize the amount of gas loading in vacuum chambers. Cluster gas jets, i.e., jets that are cooled and produce atomic clusters, are also of interest.

## FY 2006 Topics

Grant applications are also sought for the development of novel devices and instrumentation for use in the cooling (transverse and longitudinal emittance reduction) of muon beams. Approaches of interest include the development of: (1) concepts or devices for ionization cooling, including emittance exchange processes; (2) instrumentation for muon cooling channels that have muon intensities of  $10^{12}$  muons/pulse; or (3) fast (on the order of 10 picosecond) timing detectors for muon cooling experiments with low muon intensity (on the order of  $10^5$  muons/second).

Finally, the so-called non-scaling Fixed Field Alternating Gradient (FFAG) systems are becoming of interest for many applications, including muon acceleration for a neutrino factory. Grant applications are sought for (1) the development and analysis of FFAG designs that contain insertion sections, (2) engineering design and cost analysis of injection and extraction systems for a neutrino factory FFAG, including the effect of the kicker system on the beam dynamics, and (3) detailed analysis of the dynamics of recently proposed non-scaling FFAG designs, including such features as dynamic aperture (and how it depends on acceleration rate) and sensitivity to errors.

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**c. Inexpensive High Quality Electron Sources**—Grant applications are sought for the design and prototype fabrication of small, inexpensive (<\$1 million) electron sources for use in advanced accelerator R&D laboratory experiments. The following parameters are target values for accelerator research experiments: (1) energy range of 5 to 35 MeV providing, at a minimum, on the order of  $10^9$  electrons in a bunch less than 5 picoseconds long; (2) normalized transverse beam emittance  $\leq 5\pi$  mm-mrad; and (3) pulse repetition rate  $>10$  Hz. Grant applications are also sought for sources with significantly lower bunch charges, energies, and emittances from a matrix cathode, but at comparable or greater peak currents and significantly higher repetition rates. In addition, grant applications are sought to develop a bright direct-current/radio-frequency (DC/RF) photocathode electron source that combines a pulsed high-electric-field DC gun and a high field RF accelerator, operates at a repetition rate of several kHz, and has electron bunch specifications similar to those listed above.

Grant applications are also sought for the development of RF photocathodes (robust, with quantum efficiencies  $>0.1$  percent) or other novel RF gun technologies operating at output electron beam energies  $>3$  MeV. Also of interest are laser or electron driven systems for such guns.

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**d. Computer Software for Control Systems and Advanced Accelerator Modeling**—Grant applications are sought to develop new or improved computational tools specifically for the design, study, or operation of charged-particle-beam optical systems, accelerator systems, or accelerator components. Such applications should incorporate the innovative development of user-friendly interfaces, with emphasis on graphical user interfaces and windows. Grant applications are also sought for the conversion of existing codes to incorporate such interfaces, provided that existing copyrights are protected and that applications include the authors' statements of permission where appropriate.

Grant applications are sought to develop improved simulation packages for injectors or photoinjectors. Areas of interest include: (1) improved space-charge algorithms; (2) improved algorithms for the self-consistent computation of the effects of wakefields and coherent synchrotron radiation on the detailed beam dynamics; (3) improved fully three-dimensional algorithms for the modeling of transversely asymmetric beams; and (4) explicit end-to-end simulations that provide for more accurate beam-quality calculations in full injector systems. Improved simulation packages also are of interest for the ionization cooling of muon beams, for instance, by modifying the scattering algorithms to improve agreement with new experimental data.

## FY 2006 Topics

Grant applications are also sought to develop: (1) improved software systems for command and control functions, real time database management, real-time or off-line modeling of the accelerator system and beam, and status display systems encountered in state-of-the-art approaches to accelerator control and optimization; and (2) improved decision and database management tools, specifically for use in planning and controlling the integrated cost, schedule, and resources in large HEP R&D and construction projects.

Grant applications are also sought to develop real-time optical networks for pulsed-accelerator control. These networks require timing information to be combined with data-communication functions on a single optical fiber connected to pulsed device-controllers. The single fiber should provide each controller with an RF-synchronized clock that has the following features: (1) an arrival time that is phase-locked to the temperature-stabilized RF reference phase, (2) a phase-locked machine pulse fiducial point, (3) digital data for machine pulse-type selection and specific pulse identification, and (4) real-time-streaming pulsed waveform data-acquisition capabilities. The controllers serve as interfaces to systems that provide such functions as low-level RF signal generation, modulator control, beam position monitors, and machine protection system sensing. The network should provide real-time, fast-feedback loop closure and TCP/IP connectivity for slow control functions, such as database access, device configuration, and code downloading and debugging.

Finally, grant applications are sought to develop real-time processors and software for pulsed accelerator control and monitoring. The software should be based on a multiprocessor architecture that can be deeply embedded within pulsed device-controllers, which employ system-on-a-chip, field-programmable gate-array, or application-specific integrated circuit technologies. The architectures should feature distinct processors for real-time pulse-to-pulse functions, and conventional slow control functions. Architectural provisions for supporting machine protection functions via an additional processor or dedicated hardware should also be included.

For the preceding two paragraphs, proposed solutions should be engineered to include: (1) resistance to electromagnetic interference generated by nearby, large, pulsed-power systems; and (2) maximum availability in remote deployment locations.

Questions – Contact LK Len ([lk.len@science.doe.gov](mailto:lk.len@science.doe.gov))

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### 39. RADIO FREQUENCY ACCELERATOR TECHNOLOGY FOR HIGH ENERGY ACCELERATORS AND COLLIDERS

The DOE High Energy Physics (HEP) program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this research in: (1) high gradient accelerator structures, (2) high peak power radio frequency (RF) technologies, and (3) new concepts for low-cost, very efficient, pulse power modulators. Relevance to applications in HEP must be explicitly described. RF accelerator R&D more appropriate to applications in nuclear physics is specifically excluded from this topic and should be submitted under Topic 48. Grant applications that propose using resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**



## FY 2006 Topics

**a. Radio Frequency Acceleration Structures**—Grant applications are sought for research on very high gradient RF accelerating structures, normal or superconducting, for use in accelerators and storage rings. Gradients  $>100$  MV/m for electrons and  $>10$  MV/m for protons in normal cavities are of particular interest, as are means for suppressing unwanted higher-order modes and reducing costs. In muon accelerator R&D, techniques for achieving gradients of 5-20 MV/m in cavities with frequencies between 5 and 400 MHz (including superconducting cavities whose resonant frequencies can be rapidly modulated) are of interest. Methods for reducing surface breakdown and multipactoring (such as surface coatings or special geometries) and for suppressing unwanted higher order modes also are of interest, as are studies of surface breakdown and its dependence on magnetic field. Grant applications should be applicable to devices operating at frequencies from 1 to 40 GHz, or between 5 and 400 MHz for muon accelerators.

Grant applications are also sought to develop simulation tools for modeling high-gradient structures, in order to predict such experimental phenomena as the onset of breakdown, post breakdown phenomena, and the damage threshold. Specific areas of interest include the modeling of: (1) surface emission, (2) material heating due to electron and ion bombardment, (3) multipactoring, and (4) ionization of atomic and molecular species. Approaches that include an ability to import/export CAD descriptions, a friendly graphical user interface, and good data visualization will be a plus.

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**b. Radio Frequency Power for Linear Accelerators**—Grant applications are sought to develop new concepts, high-power RF components, and instrumentation for use in producing high peak power in narrow-band, low-duty-cycle, and low-pulse-repetition-frequency (approximately 0.1 to 1 kHz) pulsed RF amplifiers. The principal application will be for future large multi-TeV electron/positron linear colliders. Of particular interest are innovations related to cost saving, manufacturability, and electrical efficiency. Also of interest are RF sources for high-gradient accelerator research.

Grant applications are sought for the development of RF sources at K- to Ka-band, with a power level of  $\sim 50$  MW, a pulse width of  $\sim 1$   $\mu$ s, and a repetition rate of 100 Hz. The frequency stability and output spectrum must be suitable for driving a linac. Innovations that allow the source to be configured for different frequencies at low cost are of particular interest. In addition, grant applications are sought to develop electron beam sources, such as sheet or elliptical beams, relevant to the abovementioned high power RF applications.

The next generation of multi-TeV linear colliders will require many RF power handling components which are not presently available, e.g., RF windows, couplers, mode transformers, RF loads, and high power rings capable of operating at high pulse powers. Consequently, grant applications are sought to develop active or passive RF pulse compression systems capable of handling peak powers of 150-200 MW and 100-200-nanosecond pulsewidth at 30 GHz. Grant applications are also sought for passive and active RF components such as over-moded mode converters (e.g., rectangular to circular waveguide and vice versa), high-power RF windows, circulators, isolators, switches, and quasi-optical components.

Lastly, grant applications are sought for new concepts, approaches, or designs for radio-frequency amplifiers, or pulse compression schemes, for use in the acceleration and ionization cooling channels of a future muon collider. The amplifiers or compressors must have high peak power ( $>30$  MW) and pulsed, low frequency (from 2 ms pulses at 20 MHz to 0.1 ms pulses at 200 MHz). Higher power ( $>100$  MW) pulsed sources at higher frequencies, e.g., 30  $\mu$ s at 400 MHz, also are of interest. All muon collider amplifiers must have moderate repetition rate capability (e.g., 15 Hz). Grant applications should address the cost per unit of peak power, including the cost of required power supplies.

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## FY 2006 Topics

**c. New Concepts or Components for Pulsed Power Modulators and Energy Storage**—Most RF power sources for future linear colliders require high peak-power pulse modulators of considerably higher efficiency than presently available. Grant applications are sought for new types of modulators in the 400 kV – 1 MV range for driving currents of 200 - 800 A, with pulse lengths of 0.2 – 5.0  $\mu$ s, and with rise- and fall-times less than 0.5  $\mu$ s. Grant applications also are sought for the development of modulators with improved voltage control for RF phase stability in some alternate RF power systems, as well as cathode modulators that are compact and cost competitive compared to present cathode pulse modulator schemes. Grant applications should address issues related to cost saving, manufacturability, and electrical efficiency in modulators.

Grant applications are also sought to develop improved high power solid-state switches for pulse power switching. For some applications, requirements will include the ability to switch high current pulses (2-5 kA) at voltage levels of 2 to 6 kV with switching times less than 300 nsec. These switches must handle very high di/dt (20 kA/ $\mu$ s) at low duty cycle (<0.1%).

Existing Insulated Gate Bipolar Transistor (IGBT) packages for high voltage (> 3.3kV) and high pulsed current (> 3 kA peak, 59 A average) are not optimized for very high speed pulsed power applications (6.6 MW peak for 3.2  $\mu$ s at 120 Hz) due to failure modes induced by very rapid fall times (di/dt >10 kA/ $\mu$ s) and/or rise times (dV/dt >15 kV/ $\mu$ s) upon device turn-off. Therefore, grant applications are sought to reduce these failure modes through improved packaging of commercial IGBT chips, by incorporating appropriate protective circuitry in a high voltage power package designed specifically for high-speed transients.

Lastly, grant applications are sought to develop and optimize high reliability, high-energy-density energy storage capacitors for future solid state pulse power systems. The capacitors must: (1) deliver high peak pulse current (5 - 8 kA) in the partial discharge region (less than 10 percent voltage droop during pulse); (2) be designed with very low inductance connections to allow fast rise and fall time discharge without ringing (di/dt ~ 20 kA/ $\mu$ s); and (3) be packaged to meet the requirements of high power solid state board layouts and have minimum production cost.

Questions – Contact LK Len ([lk.len@science.doe.gov](mailto:lk.len@science.doe.gov))

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## 40. HIGH-FIELD SUPERCONDUCTOR AND SUPERCONDUCTING MAGNET TECHNOLOGIES FOR HIGH ENERGY PARTICLE COLLIDERS

The Department of Energy High Energy Physics program supports a broad research and development (R&D) effort in the science, engineering, and technology of charged particle accelerators, storage rings, and associated apparatus. Advanced R&D is needed in support of this research in high-field superconductor and superconducting magnet technologies. This topic addresses only those superconductor and superconducting magnet development technologies that support dipoles, quadrupoles, and higher order multipole corrector magnets for use in accelerators, storage rings, and charged particle beam transport systems. Grant applications that propose the use of third party resources (such as a DOE laboratory) must include in the application a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

**a. High-Field Superconductor Technology**—Grant applications are sought to develop new or improved superconducting wire technologies for magnets that operate at a minimum of 12 Tesla (T) field, with increases up to 15 to 20 T sought in the near future (five to eight years). Vacuum requirements in accelerators and storage rings favor operating temperatures of 1.8 to 20 K. Stability requirements for magnets dictate that the effective filament diameter should be less than 30 micrometers. New or improved technologies must demonstrate: (1) property improvements such as higher critical current densities and higher upper critical fields, (2) the manageable degradation of these properties as a function of applied strain, and (3) low losses in changing transverse magnetic fields, such as for twisted round multifilamentary wires. Any proposed process improvements must result in equivalent performance at reduced cost. All grant applications must focus on conductors that will be acceptable for accelerator magnets, especially with regard to the operating conditions mentioned above, and must address plans to physically deliver a sufficient amount of material for winding and testing in small dipole or quadrupole magnets.

## FY 2006 Topics

Grant applications are also sought to develop improvements in the starting raw materials and the basic superconducting materials for niobium-titanium (Nb-Ti) alloys, A-15 compounds (such as Nb<sub>3</sub>Sn and Nb<sub>3</sub>Al), high-temperature superconductors (HTS; such as Bi<sub>2</sub>Sr<sub>2</sub>CaCu<sub>2</sub>O<sub>8</sub> and YBa<sub>2</sub>Cu<sub>3</sub>O<sub>7-δ</sub>), and magnesium diborides (MgB<sub>2</sub> and its alloyed variants). *Regarding Nb-Ti alloys:* High performance Nb-Ti alloys operating above 8 T continue to be required for focusing quadrupole magnets or for graded windings in the low-field portions of high-field magnets; therefore, grant applications are sought to develop Nb-Ti composite superconductors with properties optimized at 8 T fields and higher at 4.2 K. *Regarding A-15 compounds:* A minimum current density of 1800 A mm<sup>-2</sup> at 15 T and 4.2 K must be achieved in the superconductor itself. *Regarding HTS:* A minimum current density of 1200 A mm<sup>-2</sup> (not A cm<sup>-2</sup>) must be achieved in the superconductor itself, and a minimum current density of 250 A mm<sup>-2</sup> must be achieved over the total conductor cross section at 12 T minimum and 4.2 K. *Regarding MgB<sub>2</sub>:* present wires are characterized by a filling factor that is too low, wire cross-sections that have too few filaments, and upper critical and irreversibility fields that are too low; therefore, grant applications should seek to improve the current density over the wire cross-section, implement restacked round-wire multifilamentary designs, and extend the field at which a critical current density can be attained over the superconductor cross-section of 1200 A mm<sup>-2</sup> in the 12-16 T range at 4.2 K.

Grant applications are also sought to develop: (1) innovative wire processing technologies, and (2) innovative insulating materials that are compatible with the use of intermetallic superconductors in practical devices. Innovative wire processing technologies of interest include methods to utilize stranded conductors with high aspect ratio, such as Rutherford cables, or low-loss tape geometries in particle accelerator applications; technologies to improve wire piece length and increase billet mass also are of interest. Innovative insulating materials should enable the use of intermetallic superconductors, such as the A-15, HTS, or MgB<sub>2</sub> types, in practical devices. Insulating systems must: be compatible with high temperature reactions in the 750-900 °C range; be capable of supporting high mechanical loads at both room and cryogenic temperatures; have a high coefficient of thermal conductivity; be resistant to radiation damage; and exhibit low creep and low out-gassing rates when irradiated.

Questions – Contact Bruce Strauss ([bruce.strauss@science.doe.gov](mailto:bruce.strauss@science.doe.gov))

**b. Superconducting Magnet Technology**—Grant applications are sought to develop: (1) improved instrumentation to measure properties (such as local strain, temperature, and magnetic field) which are directly applicable to the testing of superconducting magnets; (2) improved current leads based on high-temperature superconductors for application to high-field accelerator magnets, which have requirements that include an operating current level of 5 kA or greater, stability, low heat leak, and good quench performance; (3) alternative designs, to traditional "cosine theta" dipole and "cosine two-theta" quadrupole magnets, that may be more compatible with the more fragile A-15, and the HTS, high-field superconductors; (4) designs for bent (e.g., bending radius in the range 0.75 to 1.25m) solenoids (e.g., 2 T, 30 cm inside diameter) with superimposed dipole fields (e.g., 1 T) for dispersion generation in large emittance beams; (5) improved industrial fabrication methods for magnets such as welding and forming; or (6) improved cryostat and cryogenic techniques.

Questions – Contact Bruce Strauss ([bruce.strauss@science.doe.gov](mailto:bruce.strauss@science.doe.gov))

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## 41. HIGH ENERGY PHYSICS DETECTORS

The DOE supports research and development in a wide range of technologies essential to experiments in HEP and to the accelerators at DOE high energy accelerator laboratories. The development of advanced technologies for particle detection and identification for use in HEP experiments or particle accelerators is desired. Principal areas of interest include particle detectors based on new techniques and technological developments (e.g., superconductivity or solid-state devices) or detectors which can be used in novel ways as a consequence of associated technological developments in electronics (e.g., sensitivity or bandwidth), with particular interest in devices exhibiting insensitivity to very high radiation levels. Also of interest are novel experimental systems that use new detectors, or use old ones in new ways, that either extend basic HEP experimental research capabilities or result in less costly and less complex apparatus. Grant applications must clearly and specifically indicate their particular relevance to HEP programmatic activities.

Although particle physics detector development is often concentrated at major national particle accelerator centers, there are many developmental endeavors, especially in collaborative efforts, where small businesses can make creative and innovative contributions that further develop the required advanced technologies. Nonetheless, applicants are encouraged to collaborate with active high energy elementary particle physicists at universities or national laboratories to establish mutually beneficial goals. On-line directories of appropriate researchers are available at <http://www.hep.net/sites/directories.html>. **Grant applications are sought only in the following subtopics:**

**a. Particle Detection and Identification Devices**—Grant applications are sought for novel devices in the areas of charged and neutral particle detection and identification. Examples include, but are not limited to, semiconductor particle detectors (silicon, CVD diamond, or other semiconductors), light-emitting particle



## FY 2006 Topics

detectors (scintillating materials including fibers, liquids, and crystals or Cherenkov radiators), photosensitive detectors that could be used with light-emitting detectors (photomultipliers, micro-channel plates, photosensitive semiconductors), gas or liquid-filled chambers (used for particle tracking or in electromagnetic or hadronic calorimeters, Cherenkov or transition radiation detectors). Applications are also sought for systematic studies of radiation aging of materials used in particle detectors.

The proposed devices must be explicitly related to future high-energy physics experiments, either accelerator or non-accelerator based, or to future uses in particle accelerators. **Relevant potential improvements over existing devices and techniques must be discussed explicitly** (e.g., radiation hardness, energy, position, and timing resolution, sensitivity, rate capability, stability, dynamic range, durability, compactness, cost). Electromagnetic calorimeters, also called shower counters or gamma ray detectors, must be optimized for photons with energies above 1 GeV. X-ray detectors are not relevant to this topic.

Questions – Contact Saul Gonzalez ([saül.gonzalez@science.doe.gov](mailto:saül.gonzalez@science.doe.gov))

**b. Detector Support and Integration Components**—HEP experiments frequently require high performance detector support that will not compromise the precision of the detectors. Therefore, grant applications are sought for components used to support or integrate detectors into HEP experiments. The support components must be well matched to the detectors and possess some or all of the following features: low mass, high strength or stiffness, low intrinsic radioactivity, exceptionally high or exceptionally low thermal conductivity, and low cost. Grant applications also are sought for alignment systems, cooling systems, and radiation-hard low voltage power supplies for digital and analog electronics.

The DOE supports research and development in a wide range of technologies essential to experiments in HEP and to the accelerators at DOE high energy accelerator laboratories. The development of advanced technologies for particle detection and identification for use in HEP experiments or particle accelerators is desired. Principal areas of interest include particle detectors based on new techniques and technological developments (e.g., superconductivity or solid-state devices) or detectors which can be used in novel ways as a consequence of associated technological developments in electronics (e.g., sensitivity or bandwidth), with particular interest in devices exhibiting insensitivity to very high radiation levels. Also of interest are novel experimental systems that use new detectors, or use old ones in new ways, that either extend basic HEP experimental research capabilities or result in less costly and less complex apparatus. Grant applications must clearly and specifically indicate their particular relevance to HEP programmatic activities.

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Questions – Contact Saul Gonzalez ([saül.gonzalez@science.doe.gov](mailto:saül.gonzalez@science.doe.gov))

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## 42. HIGH ENERGY PHYSICS DATA ACQUISITION AND PROCESSING

The DOE supports the development of advanced electronics and computational technologies for the recording, processing, storage, distribution, and analysis of experimental data that is essential to experiments and particle accelerators used for HEP research. Areas of present interest include event triggering, data acquisition, scalable clustered computer systems, distributed collaborative infrastructure, distributed data management and analysis frameworks, and distributed software development useful to HEP experiments and particle accelerators. Grant applications must clearly and specifically indicate their relevance to present or future HEP programmatic activities.

Although particle physics detector instrumentation, data processing and analysis, and software development typically occur in large collaborative efforts at national particle accelerator centers, there are efforts where small businesses can make innovative and creative contributions to further development of the required advanced technologies. Applicants are encouraged to collaborate with active high energy elementary particle physicists at universities or national laboratories to establish mutually beneficial goals. On-line directories of appropriate researchers are available by institution at <http://www.hep.net/sites/directories.html>. Grant applications that propose using the resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

## FY 2006 Topics

**a. High-Speed Electronic Instrumentation**—Grant applications are sought to develop components, electronics, systems, and instrumentation modules as follows:

- (1) Special purpose chips and devices are sought for use in the internal circuitry employed in large particle detectors. Desirable features include low noise, low power consumption, high packing density, radiation resistance, very high response speed, and/or high adaptability to situations requiring multiple parallel channels. Desirable functions include amplifiers, counters, analog pulse storage devices, decoders, encoders, analog-to-digital converters, pico-second resolution time-to-digital converters, controllers, and communications interface devices.
- (2) Circuits and systems are sought for rapidly processing data from particle detectors such as proportional wire chambers, scintillation counters, silicon microstrip detectors, particle calorimeters, and Cerenkov counters. Representative processing functions and circuits include low noise pulse amplifiers and preamplifiers, high speed counters (>300 MHz), and time-to-amplitude converters. Compatibility with one of the widely used module interconnection standards (e.g., VMEbus, PCIExpress, or high speed serial interfaces) is highly desirable, as would be low power consumption, high component density, and/or adaptability to large numbers of multiple channels.
- (3) Advanced, high speed logic arrays and microprocessor systems are sought for fast event identification, event trigger generation, and data processing with very high throughput capability. Such systems should be compatible with or implemented in one of the widely used module interconnection standards (e.g., VMEbus, PCIExpress, or high speed serial interfaces).
- (4) Much of the electronics instrumentation in use in HEP is packaged in one of the international module inter-connection standards (e.g., VMEbus, PCIExpress, or high speed serial interfaces). Therefore, grant applications are sought for modules that will provide capabilities not previously available; for substantial performance enhancement to existing types of modules; and for components, devices, or systems that will enhance or significantly extend the capability or functionality of one of the standard systems. Examples include large and/or fast buffer memories, single module computer systems (either general purpose or special purpose), display modules, interconnection systems, communication modules and systems, and disk-drive interface modules.

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**b. Large Scale Analysis Computer Systems**—Grant applications are sought to develop: (1) computer system components and supporting software enabling large scale and open use of storage networks, especially for magnetic disks, optical disks, and magnetic tapes; (2) computer system components and supporting software enabling the use of transport protocols in a more efficient manner over local and wide area networks; (3) computer software or systems for monitoring and operating heterogeneous computer systems and networks for functionality, performance, and manageability criteria (also, ease of software installation on hundreds of computers would be desired); (4) methods for integrating distributed authority and access control into distributed data systems; (5) improvements to the quality, reliability and cost effectiveness of petabyte storage systems; (6) Improvements to the reliability of cybersecurity systems protecting distributed data and storage systems; and/or (7) Improvements to the reliability and performance of wide area networks. Proposed efforts must address identified computing problems related to diverse, large scale computing systems that support particle physics analysis or accelerator control.

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## FY 2006 Topics

### **c. Distributed Collaborative Infrastructure and Distributed Data Management and Analysis**

**Frameworks**—Advanced computational tools and software are needed to strengthen the ability of dispersed particle physics researchers to collaborate and to address problems related to the acquisition, handling, storage, analysis, and visualization of large datasets by these distributed collaborations. Grant applications are sought to develop:

- (1) client-server frameworks and Web tools for creating collaborative environments, facilitating remote participation of detector experts at the data collection stage, and allowing collaborators to remotely monitor experiments;
- (2) software project management tools;
- (3) computer system components and supporting software incorporating the use of Quality of Service features generally available in wide area networks;
- (4) portable systems to hold very large collections of data of the type created in connection with the operation of very large detectors, along with data management tools;
- (5) visualization and software environments appropriate for physics analysis;
- (6) software to support data systems distributed over a wide area network;
- (7) framework, interconnects, and other peripherals which allow the use and orderly aggregation of commodity computers and computer peripherals at larger than normal scales, or at higher performance levels than usual;
- (8) software development tools for the production of computer software to meet identified problems related to distributed, large scale software development, configuration management, and data analysis – approaches of interest include distributed portable testing and Computer Aided Software Engineering, including configuration management tools for a portable, distributed environment;
- (9) Web tools for remote data selection ("skimming"); and
- (10) Algorithms and software tools for pattern recognition and optimization of data analysis.

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**d. Simulation and Modeling Techniques and Systems**—Grant applications are sought to develop advanced computing tools and software for high energy physics simulation and modeling. Topics of interest include simulation and modeling algorithms for high energy physics processes, particle detectors, and theoretical calculations. Applications are also sought in areas of simulation support such as frameworks for the management, configuration, custody, and dissemination of simulation and modeling data to enable sharing by multiple experiments and theory research groups.

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## FY 2006 Topics

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## PROGRAM AREA OVERVIEW OFFICE OF ADVANCED SCIENTIFIC COMPUTING RESEARCH

The primary mission of the Advanced Scientific Computing Research (ASCR) program, which is carried out by the Mathematical, Information, and Computational Sciences subprogram, is to discover, develop, and deploy the computational and networking tools that enable researchers in the scientific disciplines to analyze, model, simulate, and predict complex phenomena important to the Department of Energy. To accomplish this mission the program fosters and supports fundamental research in advanced scientific computing – applied mathematics, computer science, and networking – and operates supercomputer, networking, and related facilities. The applied mathematics research efforts provide the fundamental mathematical methods to model complex physical and biological systems. The computer science research efforts enable scientists to efficiently run these models on the highest performance computers available and to store, manage, analyze, and visualize the massive amounts of data that result. The networking research provides the techniques to link the data producers; e.g., supercomputers and large experimental facilities with scientists who need access to the data.

In fulfilling this primary mission, the ASCR program supports the Office of Science Strategic Plan's goal of providing extraordinary tools for extraordinary science as well as building the foundation for the research in support of the other goals of the strategic plan. In the course of accomplishing this mission, the research programs of ASCR have played a critical role in the evolution of high performance computing and networks.

For additional information regarding the Office of Advanced Scientific Computing Research priorities, [click here](#).

### 43. HIGH-PERFORMANCE COMPUTING

The High-Performance Computing (HPC) program in the Office of Science at the Department of Energy supports research that contributes to comprehensive, scalable, and robust high performance computing infrastructures. The HPC program focuses on research and development for scalable systems software, visualization systems, data management tools, and related computing technologies that can translate the promise and potential of high peak performance to real performance improvements in DOE scientific applications.

**Grant applications are sought only in the following subtopics:**

## FY 2006 Topics

**a. High-Performance Computing Software and Hardware**—Emerging large-scale science endeavors increasingly call for extreme-scale supercomputing systems. These systems, which will exploit tens to hundreds of thousands of processors, will be based on a variety of challenging architectures – from distributed memory clusters of unprecedented scale to radically different innovative architectural concepts such as PIMs, FPGAs, and complex memory hierarchies. The new supercomputing systems will differ greatly in scale and complexity from today’s systems, placing new and challenging demands on system software and related supporting hardware subsystems. Grant applications are sought to develop innovative HPC software and hardware subsystems to address the emerging need of the HPC effort in the Office Science. Areas of interest include, but are not limited to, parallel and network I/O, schedulers, queue management tools, common APIs, performance metrics and benchmarks, light-weight low-level communication mechanisms, high-speed optical interconnects, and storage systems. Grant applications for these proposed system software components and hardware subsystems must address the needs for: (1) portability and interoperability of complex high performance scientific software packages; (2) operating systems tools and support for the effective management of terascale systems and beyond; and (3) effective tools for feature identification.

Questions – Contact Thomas Ndousse-Fetter ([tndousse@science.doe.gov](mailto:tndousse@science.doe.gov))

**b. Scientific Data Management and Understanding**—Modern science is increasingly becoming a data-intensive activity, with experiments in science areas such as high-energy and nuclear physics, climate modeling, computational biology, and fusion energy estimated to generate petabyte-scale data. Given the projected wave of data and information, the importance of managing scientific data and information is recognized as being in the critical path of modern scientific endeavor. Accordingly, grant applications are sought to develop: (1) workflow data management technologies to aid the construction and automation of scientific problem-solving processes; (2) meta-data and data description services to describe and track data within and across different communities; (3) efficient data access and query technologies to handle the organization of complex scientific data that is not based on simple relational tables, as used in commercial systems; (4) distributed data management and movement services to deal with high-speed data transfer, data replication, and the associated cyber security requirements; (5) high-speed data storage and caching services to deal with high-performance data access, random I/O, and dynamic data storage and caching; and (6) data analysis services to enable next-generation scientific visualization, feature identification, and tracking.

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**c. Numerical Software Library Management and Technologies**—The Advanced Scientific Computing Research (ASCR) program has been fully or partially responsible for funding the research and development (R&D) of a wide range of robust, high-quality numerical algorithms for scientific computation. These include the development of libraries such as EISPACK, LINPACK, LAPACK, ScaLAPACK, ARPACK, CLAWPACK, PETSc, TAO, CHOMBO, ebCHOMBO, SALSA, MPSALSA, LOCA, HYPRE, SuperLU, FronTier, and many others. However, a number of critical issues must still be resolved in order to ensure that the value of the software is maintained and that the large R&D investment is maximized. These issues include the development of technologies to provide: enhanced user interfaces; distribution support; maintenance activities such as collecting and tracking bug reports, and fixing bugs; and portability across platforms (including porting to new computational architectures). Grant applications are sought to: (1) develop new maintenance and distribution mechanisms to ensure that updated scientific libraries are subjected to validation and verification testing; (2) implement formal tracking mechanisms for bug reports, bug fixes, and update notification for a wide range of scientific algorithm libraries; (3) develop and maintain mechanisms for providing cost effective portability of scientific libraries across a wide range of computer architectures, from desktop systems to massively parallel leadership-class supercomputers; (4) develop and maintain high-quality user documentation for each component of scientific software, including advice on domains of applicability for

## FY 2006 Topics

each module; and (5) develop comprehensive email- or Web-based user support services for scientific libraries. The ASCR program will assure that successful grant applicants will obtain access to relevant computational facilities, as needed, for their research.

Questions – Contact Thomas Ndousse-Fetter ([tndousse@science.doe.gov](mailto:tndousse@science.doe.gov))

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## FY 2006 Topics

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### 44. HIGH-PERFORMANCE NETWORKS

The Office of Science in the U.S. Department of Energy (DOE) increasingly depends on a wide range of high-performance networks and middleware technologies to support its science mission. Large-scale science projects coming online in the next few years (such as the Large Hadron Collider (LHC), the Spallation Neutron Source (SNS), bioinformatics, climate modeling, computational biology, etc.) call for high-performance middleware and networks with unprecedented capabilities, which, unlike today's commercial networks, can securely deliver multi-Gigabits/sec throughput to high-end scientific applications. High-performance networks and middleware technologies enable scientists to access geographically-distributed terascale computing resources, science instruments, and petabyte-scale data repositories, and also enable large-scale scientific collaborations. The current research and development (R&D) priorities to address these networking challenges are grouped in three technology focus areas: (1) ultra high-speed network technologies, (2) agile optical networks, and (3) high-speed cyber security technologies. The common thread underlying DOE networking and middleware is the end-to-end ultra-high-speed capability to securely deliver multi-Gigabits/sec (10 Gbps and beyond) to high-end science applications. Therefore, grant applications submitted in response to this topic must clearly indicate how the proposed research will address these end-to-end ultra-high-speed requirements. In addition, grant applications must indicate the relevance of the proposed work to science mission of the Office of Science. Additional information on the DOE networking requirement can be found at [DOE Science Networking Challenge: Roadmap to 2008](#). **Grant applications are sought only in the following subtopics:**

**a. Ultra High-Speed Network Components**—Emerging large-scale distributed science applications within DOE's Office of Science increasingly depend on networks with unprecedented bandwidth capabilities. These networks are anticipated to deliver multi-Gbps (10-100 Gbps) throughputs to distributed high-end applications. Network infrastructures with these capabilities require advanced network technologies that are radically different from today's commercial networks. Grant applications are sought to develop system-level network technologies that can securely deliver multi-gigabits/sec throughput to high-end scientific applications. Approaches of interest include, but are not limited to, cost effective high-speed network Interfaces, transport protocol extensions, high-speed data transfer protocols, high-speed I/O and storage systems, high-speed host protocol stacks, and secure network measurement technologies. Device level network technologies (such as laser, optical signal processing, integrated circuits/chip-level hardware components, etc.) are beyond the scope of this topic, and grant applications that focus on these technologies will be declined.

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**b. Agile Optical Networks**—The DOE operates a production high-performance IP-based network called ESnet. ESnet interconnects science facilities, supercomputer centers, and data repositories, and also enables large scientific collaborations. The current ESnet backbone is based on Packet over SONET. In the future, it is anticipated that the ESnet core network will exploit advanced optical network technologies such as GMPLS and MPLS, in order to deliver end-to-end on-demand circuits and bandwidth. Therefore, grant applications are sought to develop advanced agile optical networks for ESnet. These end-to-end system level technologies must be suitable for deployment and testing on the Ultra-Science Net (USnet), a DOE-funded an optical network testbed operated by Oak Ridge National Laboratory. (USnet is used to develop, deploy, and test advanced optical network technologies for ESnet; further information on USnet can found at: <http://www.csm.ornl.gov/ultranet/>.) Specific areas of interest in agile optical networks include, but are not limited to, GMPLS extensions for bandwidth reservation, MPLS and GMPLS security, inter-domain GMPLS signaling, hybrid packet/circuit switched technologies, integration QoS, MPLS, and GMPLS, and traffic

## FY 2006 Topics

engineering for GMPLS-based networks. Grant applications must clearly outline how the proposed technology can be deployed and tested on the USnet testbed. Device level optical networks components (such as optical cross-connect, optical amplifiers and signal processing, etc.) are beyond the scope of this topic, and grant applications that focus on these technologies will be declined.

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**c. High-Speed Network Security Systems**—Office of Science R&D activities are conducted in an open but secure science environment. In this environment, the security systems deployed to protect cyber attacks must be carefully designed and deployed, so as to not hinder scientific discoveries. Grant applications are sought to develop intelligent and scalable cyber security systems that can operate at speeds up to 10 Gbps and beyond. The proposed cyber security systems must be fast, highly robust, and transparent to end users. Technologies of interest include, but are not limited to, ultra-high-speed Intrusion Detection Systems (IDS), high-speed firewall systems, authentication systems for GMPLS control Plane, and optical network system-level network security services.

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## FY 2006 Topics

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## 45. HIGH-PERFORMANCE MIDDLEWARE AND DISTRIBUTED SYSTEMS TECHNOLOGIES

Advances in high performance network capabilities and distributed systems technologies are making it easier for large geographically dispersed teams to collaborate effectively. However, significant research questions must be addressed if co-laboratories are to achieve their potential, namely, by providing: (1) remote access to terascale computing resources and data archives; (2) remote users with an experience that approaches "being there;" and (3) remote visualization generated by analysis of large data sets and by simulation. Grant applications are sought to develop software tools and services to support coordinated and dynamic resource sharing in areas such as resource discovery, resource access, authentication, authorization to enable resource sharing and scientific collaborations. **Grant applications are sought only in the following subtopics:**

**a. Scalable Middleware Technologies**—Grant applications are sought to develop scalable middleware technologies that will (1) enable universal, ubiquitous, easy access to remote computing resources and scientific instruments; (2) facilitate collaboration among distributed science teams; and (3) enable a new generation of distributed high-end applications of interest to the DOE. Areas of interest include, but are not limited to, secure directory services, scalable authentication/authorization services, deployable LAN and WAN QoS services, wide-area distributed data management, efficient multicast capabilities, automatic resource discovery protocols, remote data access services, and network-attached memory and storage systems.

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**b. Scalable Distributed System Technologies**—Grant applications are sought to develop scalable distributed system technologies to support the emerging distributed computing network that provides dependable, consistent, pervasive, scaleable, and efficient access to various resources that are integrated into a distributed infrastructure and can be accessed wherever and whenever by DOE scientists. These resources include visualization systems, computer systems, data storage and archive systems, and scientific instruments. Areas of interest include, but are not limited to, collaborative visualization systems, collaborative problem solving services, application level fast-data-transfer toolkits, real-time analysis, group collaboration, co-scheduling

## FY 2006 Topics

distributed resources, data management tools, science portals, on-line instrumentation, and fast-data-transfer management services.

Questions – Contact Thomas Ndousse-Fetter ([tndousse@science.doe.gov](mailto:tndousse@science.doe.gov))

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## PROGRAM AREA OVERVIEW NUCLEAR PHYSICS

Nuclear physics research seeks to understand the structure and interactions of atomic nuclei and the fundamental forces and particles of nature as manifested in nuclear matter. Nuclear processes are responsible for the nature and abundance of all matter, which in turn determines the essential physical characteristics of the universe. The primary mission of the Nuclear Physics (NP) program is to develop and support the scientists, techniques, and facilities that are needed for basic nuclear physics research. Attendant upon this core mission are responsibilities to enlarge and diversify the nation's pool of technically trained talent and to facilitate transfer of technology and knowledge to support the nation's economic base.

Nuclear physics research is carried out at National accelerator facilities and through university programs. The Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF) allows detailed studies of how quarks and gluons bind together to make protons and neutrons. In an upgrade currently being developed, the CEBAF electron beam energy will be doubled from 6 to 12 GeV. The Relativistic Heavy Ion Collider (RHIC), in operation at Brookhaven National Laboratory (BNL), is forming new states of matter that have not existed since the first moments after the birth of the Universe. A beam luminosity upgrade is proposed for the future; a new electron-ion collider is also being discussed. The NP program also supports research and facility operations that are directed towards understanding the properties of nuclei at their limits of stability and of the fundamental properties of nucleons and neutrinos. This research is made possible with the Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL), and the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory (ORNL), which provide complementary facilities for stable and radioactive beams as well as a variety of species and

## FY 2006 Topics

energies. A local program of basic and applied research is supported at the 88-Inch Cyclotron of the Lawrence Berkeley National Laboratory (LBNL). In addition, the operations of accelerators for in-house research programs at four universities (Yale University, University of Washington, Texas A&M University, and the Triangle Universities Nuclear Laboratory (TUNL) at Duke University) provide unique instrumentation with a special emphasis on the training of students.

The nuclear physics program also supports non-accelerator experiments such as the Sudbury Neutrino Observatory (SNO) facility, constructed by a collaboration of Canadian, English, and U.S. supported scientists; this facility is now taking data on solar neutrino fluxes and providing the first results on the “appearance” of oscillations of electron neutrinos into another neutrino type. Yet another facility, the Rare Isotope Accelerator (RIA), which would provide a way to explore the limits of nuclear existence, is being considered. By producing and studying highly unstable nuclei that are now formed only in the stars, scientists could better understand stellar evolution and the origin of the elements.

Our ability to continue making a scientific impact on the general community relies heavily on the availability of cutting edge technology and advances in detector instrumentation, electronics, software, and accelerator design. The technical topics that follow describe research and development opportunities in the equipment, techniques, and facilities that are needed to conduct and advance nuclear physics research at existing and future facilities.

For additional information regarding the Office of Nuclear Physics priorities, [click here](#).

## 46. NUCLEAR PHYSICS SOFTWARE AND DATA MANAGEMENT

Large scale data storage and processing systems are needed to store, access, retrieve, distribute, and process data from experiments conducted at large facilities, such as Brookhaven National Laboratory’s Relativistic Heavy Ion Collider (RHIC) and the Thomas Jefferson National Accelerator Facility (TJNAF). The experiments at such facilities are extremely complex and expensive, involving thousands of detectors that produce raw experimental data at rates up to several hundred MB/sec, resulting in the annual production of data sets containing hundreds of Terabytes (TB) to a Petabyte, with many Petabytes (PB) of data expected in the near future. Many 10s to 100s of Terabytes of data per year are distributed to institutions around the U.S. and other countries for analysis now or in the near future. Research on large scale data management systems is required to support these large nuclear physics experiments. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

**a. Large Scale Data Storage**—Projections of the cost of data storage media show that magnetic disk media will soon be competitive with magnetic tape for storing large volumes of data. Because current technology keeps all disk drives powered and spinning, the infrastructure costs of operating a many-petabyte-scale disk storage system could be prohibitive. However, one characteristic of nuclear physics datasets is that most of the data is accessed infrequently. Therefore, grant applications are sought for new techniques for petabyte-scale magnetic disk systems that are optimized for infrequent data access, emphasizing lower cost and lower power usage. To the extent feasible, it is desirable that the cost should scale with the amount of data accessed rather than the total storage capacity.

Grant applications are also invited for the development of innovative storage technologies having high reliability and low cost, and which are geared toward infrequently-accessed petabyte-scale data.

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## FY 2006 Topics

**b. Large Scale Data Processing and Distribution**—Some nuclear physics facilities produce 100s of TB of data per year, soon to be PB per year. Many 10s of TB of data per year are distributed world-wide for analysis by the scientific collaborators. A recent trend in nuclear physics is to construct these data handling and distribution systems using web services or data grid infrastructure software such as Globus and Condor. In the near future, some systems will use the Open Grid Services Architecture (OGSA), which is based upon Web Services. Grant applications are sought for: (1) hardware and/or software techniques to improve the effectiveness and reduce the costs of storing, retrieving, and moving such large volumes of data, including, but not limited to, automated data replication coupled with application data catalogs, distributed storage systems of commercial off-the-shelf (COTS) hardware, and storage buffers coupled to 10 Gbps (or greater) networks; (2) hardware and/or software techniques to improve the effectiveness of computational and data grids for nuclear physics – examples include integrating the management of distributed open source Relational DataBase Management System (RDBMS) with OGSA, and developing application level monitoring services for status and error diagnosis; (3) effective new approaches to data mining, automatic structuring of data and information, and facilitated information retrieval; and (4) distributed authorization and security systems enabling single sign-on access to data distributed across many sites. Proposed infrastructure software solutions should consider and address the advantages of integrating closely with the OGSA and other new technologies. Applicants that propose data distribution projects are encouraged to contact the U.S. National Nuclear Data Center to determine relevance and possible future migration strategies into existing infrastructures.

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**c. Large Scale Data Archiving and Maintenance**—One of the legacies of experimental nuclear physics experiments is the data produced. Large projects like Gammasphere, sited at ANL, and experiments at RHIC and TJNAF produce unique data, whose measurements may never be repeated. It may take several years to complete the data analysis and publish the results. Then, in subsequent years, there may be a need to present the data in different forms, in order to facilitate comparison with new theoretical descriptions or newer experimental measurements. Therefore, it is important to preserve these data and their documentation over many years, in the context of potential changes in storage technology and the evolution of experimental groups. Grant applications are sought to develop permanent archiving, data provenance, and user-friendly Internet dissemination procedures for the data from nuclear physics experiments, along with associated detector description and calibration information. A complete data package would include raw data and the programs to read and process them; ROOT trees or n-tuples with derived physics quantities; and documentation, analysis notes, email archives, and web pages that detail the information and procedures used with the data for existing results. Examples of relevant technologies include (but are not limited to) systems for collecting, recording and preserving data-provenance metadata; tools to verify data integrity over long lifetimes; annotation tools; and data access portals to enable searching and retrieving relevant and related data and metadata.

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**d. Distributed Processing**—Large scale (thousands of CPU's) computing platforms are needed to perform theoretical calculations of Lattice Quantum ChromoDynamics (LQCD), a method of extracting the predictions of the fundamental theory of the interactions of quarks. While this science application can use virtually any supercomputer architecture efficiently, the computational demands are such that the cost effectiveness of the platform (measured in floating point operations per second per dollar, as sustained by a large scale parallel application) is a significant consideration. Clusters would be an appropriate platform for these calculations because of their low cost-per-compute node, but only if the cluster interconnects were of high bandwidth, low latency, and low cost. Although current offerings fall short on at least one of these metrics, the science applications are such that nearest-neighbor communications predominate in a three- or four-dimensional torus; therefore, a fully interconnected switch fabric is not essential – a torus mesh with routing also would be a feasible design. Grant applications are sought to develop mesh-communication-optimized cluster interconnects

## FY 2006 Topics

scalable to thousands of nodes at modest cost. The interconnect must be well coupled to next generation commodity compute nodes (to achieve high bandwidth and low latency on future systems) and must have a cost well below the cost of the compute node.

In a related development, grid computing is an emerging mode, sometimes called “computing on demand,” of supporting the highly distributed and intensive scientific computing for nuclear physics (and other sciences). Consequently, there is a need for software distribution and installation mechanisms that can be automated and scaled to the large numbers (100s) of computing facilities distributed around the country and the globe. Such software solutions would enable rapid access to computing resources as they become available to users who do not have the necessary application software environment installed. Grid deployments such as the Open Science Grid (OSG) in the U.S. and the LHC Computing Grid (LCG) in Europe provide standardized infrastructures for scientific computing across large numbers of distributed facilities. Grant applications are sought to develop mechanisms and tools that enable efficient and rapid packaging, distribution, and installation of nuclear physics application software on distributed computing facilities such as the OSG and LCG.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

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9. *Condor: High Throughput Computing* Website, University of Wisconsin. (URL: [www.cs.wisc.edu/condor/](http://www.cs.wisc.edu/condor/))
10. *Towards Open Grid Services Architecture* Website, University of Chicago. (URL: [www.globus.org/ogsa](http://www.globus.org/ogsa))
11. *Web Services Description Language* Website, World Wide Web Consortium. (URL: <http://www.w3.org/TR/wsdl>)



## FY 2006 Topics

12. *Open Science Grid and the Open Science Grid Consortium Website*, National Science Foundation and U.S. Department of Energy. (URL: <http://www.opensciencegrid.org/>)

13. *LHC Computing Grid and EGEE*, <http://lcg.web.cern.ch/LCG/>, <http://public.eu-egee.org/>

### 47. NUCLEAR PHYSICS ELECTRONICS DESIGN AND FABRICATION

The DOE seeks developments in detector instrumentation electronics with improved energy, position and timing resolution, sensitivity, rate capability, stability, dynamic range, durability, pulse-shape discrimination capability, and background suppression. Of particular interest are innovative readout electronics for use with the nuclear physics detectors described in Topic 49. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

**a. Advances in Digital Electronics**—Digital signal processing electronics are needed to replace analog signal processing in nuclear physics applications. Grant applications are sought to develop: (1) digital pulse processors that simplify or replace analog designs and have sufficient flexibility to incorporate such features as pile-up rejection and ballistic deficit correction; (2) digital pulse-processing electronics, including pulse-shape discrimination, for commonly used nuclear physics detectors in general, and for position sensitive solid-state detectors or highly segmented CdZnTe detectors in particular; and (3) fast digital processing electronics that improve the accuracy of the analog electronics, such as in determining the position of interaction points (of particles or photons) to an accuracy smaller than the size of the detector segments.

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**b. Circuits**—Grant applications are sought to develop custom designed integrated circuits, as well as for circuits (including firmware) and systems, for rapidly processing data from highly segmented, position-sensitive germanium detectors (pixel sizes of approximately 1 cm<sup>2</sup>) and from particle detectors (e.g., gas detectors, scintillation counters, silicon drift chambers, silicon strip detectors, particle calorimeters, and Cherenkov counters) used in nuclear physics experiments. Areas of specific interest include: (1) representative circuits such as low noise preamplifiers, amplifiers, peak sensors, analog storage devices, analog-to-digital and time-to-digital converters, transient digitizers, and time-to-amplitude converters; (2) multiple sampling ASICs, to allow for pulse-shape analysis; (3) readout electronics for solid-state pixilated detectors, including interconnection technologies and amplifier/sample-and-hold integrated circuits; and (4) constant-fraction discriminators with uniform response for low and high energy gamma rays. These circuits should be fast; low-cost; high-density; configurable in software for thresholds, gains, etc.; easy to use with commercial auxiliary electronics; low power; compact; and efficiently packaged for multi-channel devices.

In addition, planned luminosity upgrades at RHIC and experiments at the Large Hadron Collider will require fine-grained vertex and tracking detectors (both silicon and gas) for high particle multiplicity environments. Therefore, grant applications are sought for advances in microelectronics that are specifically designed for low-noise amplification and processing of detector signals, and that are suitable for these next generation detectors. The microelectronics and associated interconnections must be lightweight and have low power dissipation. Of particular interest are designs that minimize higher gate leakage currents due to tunneling and maintain dynamic range.

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## FY 2006 Topics

**c. Advanced Devices and Systems**—Active Pixel Sensors in CMOS (complementary metal-oxide semiconductor) technology are replacing Charge Coupled Devices as imaging devices and cameras for visible light. Several laboratories are exploring the possibility of using such devices as direct conversion particle detectors. The charge produced by an ionizing particle in the epitaxial layer is collected by diffusion on a sensing electrode in each pixel. The charge is amplified by a relatively simple low noise circuit in each pixel and read out in a matrix arrangement. If successful, this approach would make possible high-resolution, position-sensitive particle detectors with very low mass (approximately 50 microns of silicon in a single layer). This approach would be superior to the present technology that uses a separate silicon detector layer, which is bump-bonded to a CMOS readout circuit. Grant applications are sought to advance the development of integrated detector-electronics technology, using CMOS monolithic circuits as particle detectors. The new active pixel detector with its integrated electronic readout should be based on a standard CMOS process. The challenge is to design a sensor with low noise readout circuits that have sufficiently high sensitivity and low power dissipation, in order to detect a minimum ionizing particle in a thin “epitaxial-like” or equivalent layer (~10-30 microns).

Grant applications are also sought for the next generation of active pixel, or even strip, sensors which use the bulk silicon substrate as the active volume. This more advanced approach would have the advantage of developing relatively larger signals and allowing sensitivity to non-minimum ionizing particles such as MeV-range gamma rays.

Lastly, grant applications are sought for improved or advanced devices and systems used in conjunction with the electronic circuits and systems described in subtopics a and b. Areas of interest regarding these devices include radiation-hardened, wide-bandgap semiconductors (i.e., semiconductor materials with bandgaps greater than 2.0 electron volts, including Silicon Carbide (SiC), Gallium Nitride (GaN), and any III-Nitride alloys), inhomogeneous semiconductors such as SiGe; and device processes such as silicon-on-insulator (SOI) or silicon-on-sapphire (SOS). Areas of interest regarding systems include bus systems, data links, event handlers, multiple processors, trigger logics, and fast buffered time and analog digitizers. For detectors that generate extremely high data volumes (e.g., >500 GB/s), advanced high-bandwidth data links are of interest. Also of interest are generalized software and hardware packages, with improved graphic and visualization capabilities, for the acquisition and analysis of nuclear physics research data.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

**d. Manufacturing and Advanced Interconnection Techniques**—Grant applications are sought to develop: (1) manufacturing techniques for large, thin, multiple-layer printed circuit boards (PCBs) with plated-through holes, dimensions from 2m x 2m to 5m x 5m, with thickness from 100 to 200 microns (these PCBs would have use in cathode pad chambers, cathode strip chambers, time projection chamber cathode boards, etc); (2) techniques to add plated-through holes in a reliable, robust way to large rolls of metallized mylar or kapton (this would have applications in detectors such as time expansion chambers or large cathode strip chambers); and (3) miniaturization techniques for connectors and cables with 5 times to 10 times the density of standard interdensity connectors.

In addition, many next-generation detectors will have highly segmented electrode geometries with 5-5000 channels per square centimeter, covering areas up to several square meters. Conventional packaging and assembly technology cannot be used at these high densities. Grant applications are sought to develop: (1) advanced microchip module interconnect technologies that address the issues of high density, area-array connections including modularity, reliability, repair/rework, and electrical parasites; (2) technology for aggregating and transporting the signals (analog and digital) generated by the front-end electronics, and for distributing and conditioning power and common signals (clock, reset, etc.); (3) low-cost methods for efficient cooling of on-detector electronics; (4) low-cost and low-mass methods for grounding and shielding; and (5)

## FY 2006 Topics

standards for interconnecting ASICs (which may have been developed by diverse groups in different organizations) into a single system for a given experiment – these standards should address the combination of different technologies, which utilize different voltage levels and signal types, with the goal of reusing the developed circuits in future experiments.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

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## FY 2006 Topics

- \* Available from National Technical Information Service (NTIS). Telephone: 1-800-553-6847. Website: <http://www.ntis.gov/> (Search by order no. Please note: Items that appear to be unavailable via the Website might be obtained by phoning NTIS.)
- \*\* Abstract and ordering information available at: <http://www.sciencedirect.com/science/publications/journal/physics>.

## 48. NUCLEAR PHYSICS ACCELERATOR TECHNOLOGY

The Nuclear Physics program of the Department of Energy (DOE) supports a broad range of activities aimed at research and development related to the science, engineering, and technology of heavy-ion, electron, and proton accelerators and associated systems. Research and development is desired that will advance fundamental accelerator technology and its applications to nuclear physics scientific research. Areas of interest include the basic technologies of the Brookhaven National Laboratory's Relativistic Heavy Ion Collider (RHIC), with heavy ion beam energies up to 100 GeV/amu and polarized proton beam energies up to 250 GeV; technologies associated with RHIC luminosity upgrades and the development of an electron-ion collider; linear accelerators such as the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (TJNAF); and development of devices and/or methods that would be useful in the generation of intense accelerated beams of radioactive isotopes related to the construction of a Rare Isotope Accelerator (RIA) facility. A major focus in all above cases is superconducting radio frequency (rf) acceleration and its related technologies. Relevance of applications to nuclear physics must be explicitly described. Grant applications that propose using the resources of a third party (such as a DOE laboratory) must include, in the application, a letter of certification from an authorized official of that organization. **Grant applications are sought only in the following subtopics:**

**a. Materials and Components for Radio Frequency Devices**—Grant applications are sought to improve or advance superconducting and room temperature materials or components for rf devices used in particle accelerators. Areas of interest include: (1) peripheral components, for both room temperature and superconducting structures, such as ultra high vacuum seals, terminations, cryogenic radio frequency windows, rf power couplers, and magnetostrictive or piezoelectric cavity tuning mechanisms; (2) materials that efficiently absorb microwaves from 2 to 90 GHz and are compatible with ultra-high vacuum, particulate-free environments at 2 to 4 K; (3) methods for manufacturing superconducting radio-frequency ( $>500$  MHz) accelerating structures with  $Q_0 > 10^{10}$  at 2.0 K; (4) improved superconducting materials that have lower rf losses, operate at higher temperatures, and/or have higher rf critical fields than sheet niobium; (5) innovative designs for hermetically sealed helium refrigerators and other cryogenic equipment that simplify procedures and reduce costs associated with repair and modification; (6) development of simple, low-cost mechanical techniques for damping length oscillations in accelerating structures, effective in the 10-300 Hz range at 2 Kelvin; and (7) development of techniques to create a layer of niobium on the interior of a copper elliptical cavity, such as by energetic ion deposition, so that the resulting 700-1500 MHz structures have  $Q_0 > 8 \times 10^9$  at 2 K and so that overall fabrication costs are reduced relative to using sheet niobium.

Grant applications are also sought for the design, computer-modeling, and hardware development of 5 kW and 13 kW continuous wave (cw) power sources at 1497 MHz and 1 MW cw rf power sources at 704 MHz. Examples of candidate technologies include (but are not limited to): solid-state devices, multi-cavity klystrons, Inductive-Output Tubes (IOT's), or hybrids of those technologies. For 1497 MHz, the devices should: (1) be capable of operating efficiently over a range of output power levels; (2) include a method for power adjustment other than using the rf drive signal and the voltage of any primary dc source – for example, a klystron should include a gun-current modulating electrode; and (3) have an ac-to-rf conversion efficiency greater than 50%. Interested parties should contact Dr. Leigh Harwood at Jefferson Laboratory [harwood@jlab.org] or Dr. Ilan Ben-Zvi at Brookhaven National Laboratory ([ILAN@BNL.GOV](mailto:ILAN@BNL.GOV)) for further specifications.

## FY 2006 Topics

Lastly, grant applications are sought to develop technology that would provide more cost effective, kW-level liquid helium refrigerators. Such technology is needed because the cost effectiveness of a superconducting rf accelerator, typically operating at a temperature of 2 K or below, scales strongly with the cost of liquid helium.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

**b. Design and Operation of Radio Frequency Beam Acceleration Systems**—Grant applications are sought for the design, fabrication, and operation of radio frequency accelerating structures and systems for heavy-ion accelerators. Areas of interest include: (1) continuous wave (cw) structures, both superconducting and non-superconducting, for the acceleration of beams in the velocity regime between 0.001 and 0.01 times the velocity of light and with charge-to-mass ratios between 1/30 and 1/240; (2) superconducting rf accelerating structures appropriate for RIA drivers, for particles with speeds in the range of 0.02-0.8 times the speed of light; (3) innovative techniques for field control of ion acceleration structures (1° of phase and 0.1% amplitude) and electron acceleration structures (0.1° of phase and 0.01% amplitude) in the presence of 10-100 Hz variations of the structures' resonant frequencies (0.1-1.5 GHz); (4) multi-cell, superconducting, 0.5-1.5 GHz accelerating structures that have sufficient higher-order mode damping for use in energy-recovering linac-based devices with ~1 A of electron beam; (5) methods for preserving beam quality by damping beam-break-up effects in the presence of otherwise unacceptably-large higher-order cavity modes – one example of which would be a very high bandwidth feedback system; (6) methods and/or devices for reducing the emittance of relativistic ion beams – such as electron or optical-stochastic cooling; and (7) development of tunable superconducting rf cavities for acceleration and/or storage of relativistic heavy ions.

Grant applications are also sought to develop and demonstrate low level rf system control algorithms or control hardware that provide a robust and adaptive environment suitable for any rf system. Of special interest are approaches that address the particular challenges of superconducting rf systems, but room temperature systems are of interest as well.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

**c. Particle Beam Sources and Techniques**—Grant applications are sought to develop: (1) particle beam ion sources with improved intensity, emittance, and range of species (areas of interest include high-charge-state sources for heavy ions, sources for negative and light ions, and polarized sources for hydrogen ions and electrons); (2) ion sources for radioactive beams (emphasizing aspects such as high efficiency, high-charge-state ions, small emittance and energy spread, high temperature operation for coupling to high temperature production targets, and element selectivity – e.g., through the use of laser ionization); (3) techniques for secondary radioactive beam collection, charge equilibration, and cooling; (4) methods and devices to increase the charge state of ion beams (e.g., by the use of special electron-cyclotron-resonance ionizers or special stripping techniques); (5) high brightness electron beam sources utilizing continuous wave (cw) superconducting rf cavities with integral photocathodes operating at high acceleration gradients; (6) ~1 GHz cw polarized electron sources delivering beams of ~10 mA with longitudinal polarization of ~80%; (7) ~28 MHz cw polarized sources delivering beams of ~500 mA with ~80% polarization; (8) novel high quantum efficiency, long life photocathode materials, such as chalcopyrites, for high brightness electron sources with polarizations >90%; (9) devices, systems, and sub-systems for producing high current (>200 μA), variable-helicity beams of electrons with polarizations >80%, and which have very small helicity-correlated changes in beam intensity, position, angle, and emittance; (10) methods to improve high voltage stand-off and reduce field emission from high voltage electrodes in the presence of work-function-lowering material (i.e., cesium), and which are compatible with ultra high vacuum environments; (11) wavelength-tunable (700 to 850 nm) mode-locked lasers with pulse repetition rate between 0.5 and 3 GHz and average output power >10 W; and (12) a high average



## FY 2006 Topics

power (~100 W) green laser light source, with a rf-pulse repetition rate in the range of 0.5 to 3 GHz for synchronous photoinjection of GaAs photoemission guns.

Grant applications are sought for the development of high reflectivity Vacuum Ultraviolet (VUV) mirrors with a high degree of resistance to intense synchrotron radiation. Of particular interest are the development and production of substrates and coatings for VUV mirrors, which are appropriate for gamma-ray production by electron Compton back-scattering of VUV photons produced by a free-electron laser in the wavelength bands of 193 - 155 nm, 155 - 135 nm, and below 135 nm. Interested parties should contact Prof. Ying Wu ([Wu@fel.duke.edu](mailto:Wu@fel.duke.edu)) for further information.

Grant applications are also sought to develop technology for proton and electron acceleration in the energy range of several GeV, using non-scaling fixed-field alternating gradient accelerators (FFAG). Areas of interest include: (1) development of rapidly tunable rf systems, (2) demonstration of appropriate magnetic field configurations, and (3) design of an electron model/prototype to directly simulate operation under space charge limiting conditions. The nuclear physics interest is the acceleration of charged particles in re-circulating devices. Other potential applications include high intensity proton drivers for neutron production, waste transmutation, energy production in nuclear reactors, medical proton therapy (250 MeV), and radioisotope production. The acceleration of electrons also could have application to the production of high-intensity synchrotron radiation. Interested parties should contact Dr. Dejan Trbojevic ([trbojevic@bnl.gov](mailto:trbojevic@bnl.gov)) for further information.

Lastly, grant applications are sought to develop software that adds significantly to the state-of-the-art in the simulation of such physical processes as intra-beam scattering, electron cooling, beam dynamics, transport and instabilities, electron or plasma discharge in vacuum under the influence of charged beams, etc.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

**d. Accelerator Control and Diagnostics**—Grant applications are sought for: (1) “intelligent” software and hardware to facilitate the improved control and optimization of charged particle accelerators and associated components for nuclear physics research (developments that offer generic solutions to problems in the initial choice of operation parameters and the optimization of selected beam parameters with automatic tuning are especially encouraged); (2) advanced beam diagnostics concepts and devices that provide high speed computer-compatible measurement and monitoring of particle beam intensity, position, emittance, polarization, luminosity, momentum profile, time of arrival, and energy (including such advanced methods as neural networks or expert systems and techniques that are nondestructive to the beams being monitored); (3) beam diagnostic devices that have increased sensitivities through the use of superconducting components (for example, filters based on high  $T_c$  superconducting technology or Superconducting Quantum Interference Devices); (4) measurement devices/systems for cw beam currents in the range 0.1 to 100  $\mu\text{A}$ , with very high precision ( $<10^{-4}$ ) and short integration times; (5) beam diagnostics for ion beams with intensities less than  $10^7$  nuclei/second; (6) non-destructive beam diagnostics for stored ion beams such as at the RHIC and/or for 100 mA class electron beams; (7) devices that can perform direct 12-14 bit digitization of signals at 0.5-2 GHz and have bandwidths of 100+ kHz; (8) systems for predicting insipient failure of accelerator components through the monitoring/cataloging/scanning of real-time or logged signals; (9) devices/systems that measure the emittance of intense ( $>100\text{kW}$ ) cw ion beams, such as those expected at the RIA facility; and (10) beam halo monitor systems for ion beams.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

## FY 2006 Topics

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\* Available from Springer-Verlag New York, Inc. Telephone: 800-777-4643. Website: <http://www.springer-ny.com/aip/>

## 49. NUCLEAR PHYSICS PARTICLE AND RADIATION DETECTION SYSTEMS, INSTRUMENTATION AND TECHNIQUES

The Department of Energy (DOE) is interested in supporting projects that may lead to advances in detection systems, instrumentation, and techniques for nuclear physics experiments. Opportunities exist for developing equipment beyond the present state-of-the-art and outside the usual scope of research and development activities at the nuclear physics national laboratories and university programs. In addition, a new suite of next-generation detectors will be needed for the proposed Rare Isotope Accelerator (RIA), the 12 GeV energy upgrade at TJNAF, the proposed underground laboratory, the proposed luminosity upgrade at RHIC, and a possible future electron-ion accelerator. All grant applications must explicitly show relevance to the nuclear physics program. **Grant applications are sought only in the following subtopics:**

**a. Advances in Detector and Spectrometer Technology**—Nuclear physics research has a need for devices to detect, analyze, and track charged particles, and neutral particles such as neutrons, neutrinos, photons, and single atoms. These devices include: solid-state devices such as highly segmented coaxial and planar germanium detectors, and silicon strip, pixel, and silicon drift detectors; photosensitive devices such as avalanche photodiodes, hybrid photomultiplier devices, single and multiple anode photomultiplier tubes, high-intensity ( $\sim 10^{20}$   $\gamma$ /s) gamma-ray current-readout detectors (e.g. Compton Diodes), photodiodes for operation at liquid helium temperatures with a signal-to-noise ratio comparable to a photomultiplier tube, and other novel photon detectors; detectors utilizing photocathodes for Cherenkov and UV light detection, and the development of new types of large area photo-emissive materials such as solid, liquid, or gas photocathodes; micro-channel plates; gas-filled detectors such as proportional, drift, streamer, microstrip, Gas Electron Multipliers (GEMs), Micromegas and other types of micropattern detectors, straw drift tube detectors, time projection chambers, resistive plate chambers, and Cherenkov detectors; liquid argon and xenon ionization chambers and other cryogenic detectors; single-atom detectors using laser techniques and electromagnetic traps; particle polarization detectors; electromagnetic and hadronic calorimeters, including high energy neutron detectors; and detection systems for detecting the magnetization of polarized nuclei in a magnetic field (e.g., Superconducting Quantum Interference Device (SQUIDS) or cells with paramagnetic atoms that employ large pickup loops to surround the sample). Grant applications are sought to develop advancements in the technology of the above mentioned detectors.

With respect to solid state tracking devices, such as the segmented germanium detectors and the silicon drift, strip, and pixel detectors, grant applications are sought for: (1) manufacturing techniques, including interconnection technologies for high granularity, high resolution, light-weight, and radiation-hard solid state devices; (2) highly arrayed solid state detectors for neutron detection, with integrated electronics to read-out pulse height; (3) thicker (more than 1.5 mm) segmented silicon charged-particle and x-ray detectors and associated high density, high resolution electronics; and (4) cost-effective production of n-type and p-type silicon drift chambers with active areas greater than 16 cm<sup>2</sup>.

With respect to position sensitive charged particle and photon tracking devices, grant applications are sought for the development of: (1) position sensitive, high resolution, germanium detectors capable of determining the position (to within a few millimeters utilizing pulse shape analysis) and energy of the individual interactions of gamma-rays (with energies up to several MeV), hence allowing for the reconstruction of the energy and path of

## FY 2006 Topics

individual gamma-rays using tracking techniques; (2) hardware and software needed for digital signal processing and gamma-ray tracking – of particular interest is the development of efficient and fast algorithms for signal decomposition and improved tracking programs; (3) alternative materials, with comparable resolution to germanium, but with significantly higher efficiency and relatively higher temperature operation (in order to overcome the costly and bulky requirement to cool germanium detectors to liquid nitrogen temperatures); (4) improvements and new developments in micropattern detectors – this would specifically include commercial and cost effective production of GEM foils and other types of micropattern structures, such as fine meshes used in Micromegas, as well as novel approaches that could provide high resolution multidimensional readout; (5) advances in more conventional charged-particle tracking detector systems, such as drift chambers, pad chambers, time expansion chambers, and time projection chambers (areas of interest include improved gases or gas additives that resist aging, improve detector resolution, decrease flammability, and offer larger/more uniform drift velocity); (6) high-resolution, gas-filled, time-projection chambers employing CCD cameras to perform an optical readout; (7) gamma-ray detectors capable of making accurate measurements of high intensities ( $>10^{11}$  /s) with a precision of 1-2 %, as well as economical gamma-ray beam-profile monitors; (8) for the RIA, next-generation high spatial resolution focal plane detectors for magnetic spectrographs and recoil separators, for use with heavy ions in the energy range from less than 1 MeV/u to over 100 MeV/u; and (9) a bolometer with high-Z material (e.g. W, Ta, Pb) for gamma ray detection with segmentation, capable of handling 100 -1000 gamma ray per second; (10) detectors made of more conventional materials (silicon or scintillator) capable of reconstructing multiple-Compton gamma-ray scattering with mm resolution; and (11) advances in CCD technology, particularly in areas of fast parallel, low-power readout and cross-talk control.

With respect to particle identification detectors, grant applications are sought for the development of: (1) inexpensive, large-area, high-quality Cherenkov materials; (2) inexpensive, position sensitive, large-sized photon detection devices for Cherenkov counters; (3) high resolution time-of-flight detectors; (4) affordable methods for the production of large volumes of xenon and krypton gas (which would contribute to the development of transition radiation detectors and would also have many applications in X-ray detectors); and (5) very high resolution particle detectors or bolometers (including the required thermistors) based on semiconductor materials and cryogenic techniques. Of particular interest are detector technologies capable of measuring energies of alpha particles and protons with less than 5 keV resolution, thereby allowing spectroscopy experiments using light charged particles to be performed in the same way as spectroscopy experiments using gammas.

Grant applications are also invited for development of systems for predicting insipient failure of detector components through the monitoring/cataloging/scanning of real-time or logged signals.

Grant applications are also invited for innovative design of high-resolution particle separators needed for the spectrometer research program associated with the Rare Isotope Accelerator project [15]. (Please contact Dr. J.A.Nolen, Jr [nolen@anl.gov] of Argonne National Laboratory for additional details).

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

**b. Technology for Rare Particle Detection**—Grant applications are sought for particle detectors and techniques that are capable of measuring very weak, rare event signals in the presence of significant backgrounds. Such detector technologies and analysis techniques are required in searches for rare events (such as double beta decay) and for applications in extending our knowledge of new nuclear isotopes produced at radioactive beam facilities. Rare decay and rare phenomenon detectors require large quantities of very clean materials, such as clean shielding materials and clean target materials. Neutrino detectors need very large quantities of ultra-clean water, for example.

### FY 2006 Topics

Grant applications are sought to develop: (1) ultra-low background techniques of contacting, supporting, cooling, cabling, and connecting high-density arrays of germanium detector – ultrapure materials must be used in order to keep the generated background rates as low as possible (goal is 1 micro-Becquerel per kg); (2) advanced germanium detector cooling techniques and associated infrastructure (high-density signal cabling, signal and high voltage interconnects, vacuum feedthroughs, front-end amplifier FET assemblies) to assure ultra-low levels of radioactive contaminants; and (3) measurement methods for the contaminant level of the ultra-clean materials.

Grant applications are also sought for new technologies to produce large quantities of separated isotopes, such as kg quantities of Ge-76, Se, and other materials, which are needed for rare particle and rare decay searches in nuclear physics research.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

#### **c. Large Band Gap Semiconductors, New Bright Scintillators, Calorimeters, and Optical Elements—**

Grant applications are sought to develop new materials or advancements for photon detection. Of specific interest are: (1) large band gap semiconductors such as (CdZnTe, HgI<sub>2</sub>, AlSb, etc.); (2) bright, fast scintillator materials (LaHA<sub>3</sub>:Ce, where HA=Halide) and scintillators with pulse-shape discrimination (PSD) (n/gamma and charged particle); (3) selenium based detectors (perhaps using GaSe, CdSe or ZnSe); (4) plastic scintillators, fibers, and wavelength shifters; (5) cryogenic liquid scintillation gamma ray detectors (LXe); (6) Cherenkov radiator materials with indices of refraction up to 1.10 or greater, and with good optical transparency; and (7) new and innovative calorimeter concepts, including new materials, higher packing densities, or innovative fiber and absorber packing schemes.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))

**d. Nuclear Targets and High-Radiation Environment Beam Transport Components—**Grant applications are sought to develop specialized targets for the nuclear physics program, including: (1) polarized (with nuclear spins aligned) high-density gas or solid targets; (2) frozen-spin active (scintillating) targets; (3) windowless gas targets and supersonic jet targets for use with very low energy charged particle beams; (4) liquid, gaseous, and solid targets capable of high power dissipation when high intensity, low-emittance charged-particle beams are used; (5) high-power targets with fast release capabilities for the production of rare isotopes; and (6) thin (<few micro-g/cm<sup>2</sup>) condensed phase hydrogen targets that can be well localized (1mm in all directions).

In addition, grant applications are sought to develop techniques for: (1) the production of ultra-thin films needed for targets, strippers, and detector windows – in particular, for the RIA, there is a need for stripper foils or films (in the thickness range from a few micrograms per cm<sup>2</sup> to over 10 milligrams per cm<sup>2</sup>) for use in the driver linac with very high power densities from uranium beams; and (2) the preparation of targets of radioisotopes, with half-lives in the hours range, to be used off-line in both neutron-induced and charged-particle-induced experiments.

Grant applications are also sought for techniques and strategies needed for ion beam transport in the high-radiation environment anticipated at RIA [19]. Approaches of interest include: (1) simulations to characterize radiation doses to magnets and other components near the production targets and beam dumps; (2) development of appropriate containment for activated coolants such as liquid lithium and water; and (3) development of magnet design concepts that are consistent with the radiation dose, field, and aperture requirements set by optics calculations.

Questions – Contact Blaine Norum ([blaine.norum@science.doe.gov](mailto:blaine.norum@science.doe.gov))



## FY 2006 Topics

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## FY 2006 Topics

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